FIG. 1. DISTANT THUNDERSTORMS, THE DARK CENTRAL MASSES, WITH ANVIL TOPS. (A. J. Weed, Mt. Weather, Va.) (This is the first picture of 32 on the Weather Bureau's new cloud chart. The other cloud pictures reproduced in this book are selections from the same chart.) *See* p. 152.

WHY THE WEATHER?

BY

CHARLES FRANKLIN BROOKS, Ph.D. (Harvard)
Associate Professor of Meteorology and Climatology, Clark University, Secretary, American Meteorological Society; Formerly Meteorologist, U. S. Weather Bureau

WITH THE COLLABORATION OF

JOHN NELSON AND OTHERS

ILLUSTRATED WITH PHOTOGRAPHS

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PREFACE

Why the Weather? is the outgrowth of daily explanations of the weather to classes in meteorology at Clark University. Mr. John Nelson reported these explanations of current weather for his newspaper. The apparent local interest in these weather notes led, at the instance of Mr. Nelson, to the preparation of similar but more generalized short notes, which were syndicated by *Science Service,* and have been appearing in various United States and Canadian newspapers. Mr. Nelson's experienced collaboration, of which the author is duly appreciative, extended through the first nine months of the series. Since February, 1924, Eleanor Stabler Brooks has been the only collaborator: hence she is responsible for the form of a number of the spring and late winter notes. Mrs. Brooks, in addition, wrote a few of the hot weather notes, and criticized and edited the whole series as it was being prepared. The author acknowledges heartily the unceasing interest shown by Mr. Watson Davis, of *Science Service,* beginning with his origination of the title for the series.

In this series no effort was spared to avoid inaccuracies, the bane of popularized science. Every note before publication was scrutinized by competent authority in the U. S. Weather Bureau, and changed in accordance with any comments received. The author is particularly indebted to Dr. W. J. Humphreys for his critical reading of the entire series.

Most of the photographs appearing in this book were either supplied or collected by the United States Weather Bureau. This service is gratefully acknowledged.

These notes were originally written, and are presented here in book form, primarily for the general reader who likes to know more about that much talked about, but little understood, topic—the weather. Unlike a text-book, this series can not claim to cover adequately the entire field of meteorology. It attempts, however, to include topics of general interest which serve to illustrate many phases of weather science and to emphasize fundamentals. That the reader may find this book serviceable for reference as different sorts of weather are experienced from day to day a very complete index has been provided.

CHARLES F. BROOKS.

WORCESTER, MASS.,
June 10, 1924.

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WHY THE WEATHER?

PART I: GENERAL NOTES AND SPRING WEATHER

SECTION I

OBSERVE THE WEATHER

Observe the Weather. Get into the habit of noticing the sky and its clouds, the temperature, the barometric pressure and the humidity, and make note of the phenomena which accompany their various combinations. Learn the meaning of the rising and the falling barometer. If the daily weather maps are available, watch the travels of the "highs" and "lows" across the continent, with their isobars, the lines of equal pressure, and their isotherms, the lines of equal temperature. See how they control the weather as you experience it. Even a familiarity with the ancient weather adages is helpful, if you are certain that you have culled only those based on science and discarded the many which are untrue.

Gradually the meaning of the weather signs will become familiar, and presently you will find yourself prophesying immediate changes of

weather with a much closer approach to accuracy.

Beware the Barometer. Immediately after Torricelli invented the barometer, three centuries ago, men discovered that before and during stormy periods the liquid sank, while with the onset of fair weather the liquid rose. In fine, settled weather the liquid was generally higher than usual, while in wet periods it was usually lower than the average stand. The variations were usually within a range between 29 and 30.6 inches of mercury at sea-level, 29.9 or 30.0 inches being the average. The barometer became invaluable in local weather forecasting, and it is still considered the most important instrument for this purpose.

But the barometer's indications are not so simple as the "Fair," "Changeable," "Rainy," and "Stormy," indicated on the various portions of the scale of the aneroid barometer. A high barometer is not necessarily a sign of fair weather, nor is the fact that it is low a sure sign of foul. The significant point is, Is the barometer rising or falling? No single reading can tell this. If, however, the hand on the common aneroid barometer, which has a clock face, stands at the low point of 29.5 inches (as set for sea-level) at 8 o'clock and has risen to 29.6 at 10 o'clock, it is pretty certain that

the center of the prevailing low pressure area has passed and that good weather may be expected. If, on the other hand, the reading is high, say 30.4 inches, and an hour later it is 30.35, then it is a "falling glass," as the sailors say, and bad weather may be approaching.

Smoke As Wind Indicator. Observations of smoke rising from a tall chimney are sometimes used as a guide to wind direction and velocity. If one's distance from the source of smoke is known, the velocity of the wind may be ascertained from a measurement of the angular motion of the smoke. A rough measurement of this sort can be made with a pencil held at arm's length.

Smoke as a wind indicator suffers from various limitations, however, as it is difficult to tell in what direction it is really moving. Smoke apparently moving to the right from a chimney in the north may be coming from NW., W., or SW. Smoke from two sources in different directions will usually show the wind direction accurately, however. In a calm smoke will ascend in a column; much turbulence dissipates it quickly. Up and down air currents and gustiness produce the characteristic wavy line of smoke seen by day, and a light, steady wind the straight one seen on a moonlight night.

Gaging Speed of Wind.

Who hath seen the wind?
Neither you nor I.
But when the trees bow down their heads
The wind is passing by.

—Christina Rossetti.

A person can tell approximately the speed at which wind is blowing by observing surrounding objects, especially trees and shrubbery. In a calm, smoke rises vertically. In a light air, with wind less than three miles an hour, smoke drifts, but weather vanes are not affected. In a slight breeze, about 5 miles, wind is felt on the face and leaves rustle, and in a gentle breeze, about 10 miles, wind extends a light flag, and leaves and small twigs are in constant motion. A moderate breeze, roughly 15 miles, raises dust and moves small branches. The strong breeze blows from 25 to 30 miles an hour, and sets large branches in motion and umbrellas are troublesome. In a high wind, blowing at about 35 miles an hour, whole trees are in motion, and a person breasts the blast with some difficulty. Then comes the gale, about 40 to 45 miles, when twigs are broken from trees and human progress is impeded. A strong gale blows some 50 miles an hour, a whole gale around 60 miles, and still fiercer are the storm and the hurricane.

Fig. 2. Aneroid Barometer. This convenient portable instrument gives generally reliable indications of atmospheric pressure Aneroids are commonly used for determinations of altitude.

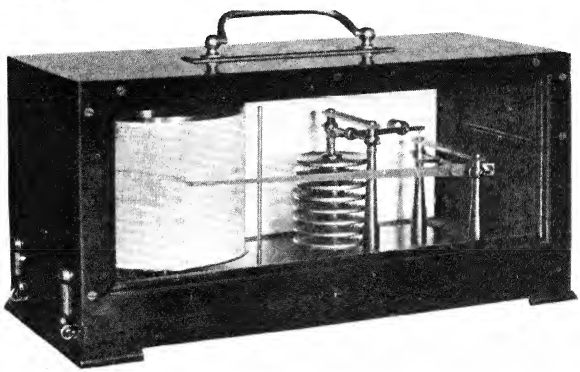


Fig. 3. Fortin Type Mercurial Barometer. This is the sort of barometer read three or more times daily at all regular U. S. Weather Bureau stations.

Fig. 4. Aneroid Barograph. This type of recording barometer is to be seen at most weather stations. On the right is a battery of vacuum boxes solidly attached at the bottom, but connected with a movable lever at the top. When the pressure falls the reduced pressure on the boxes allows the springs in them to expand. The movement is magnified at the end of the long pen arm, which writes on the revolving clock cylinder, at the left. *See* pp. 4 and 5.

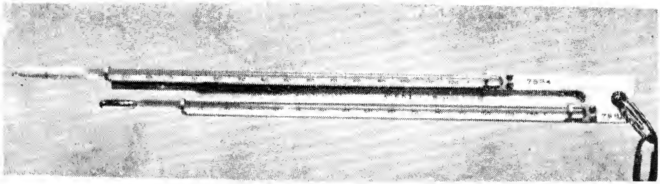


FIG. 5. SLING PSYCHROMETER. This is the standard instrument used for determining air temperatures and humidities. The muslin covered bulb is wetted, and then both thermometers are rapidly whirled to bring much air into contact with the bulbs. Wet and dry bulb temperatures are noted, and the humidity is found from tables.

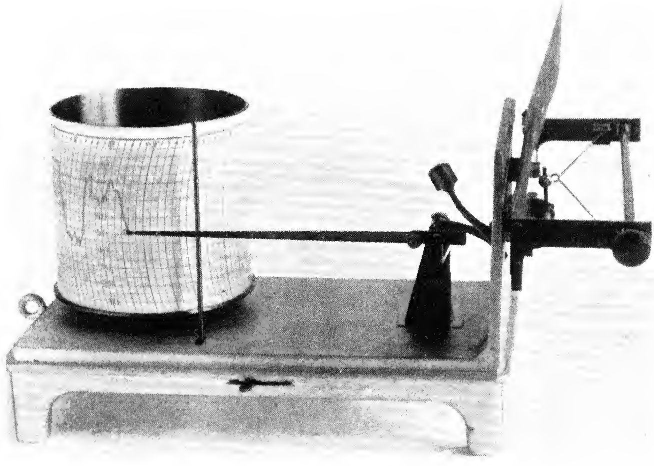


FIG. 6. HAIR HYGROGRAPH. A convenient type of directly recording relative humidity instrument is this hair hygrograph used at many U. S. Weather Bureau stations. On the right is a bundle of human hairs that have been treated with alcohol. No matter what the air temperature, these hairs change length almost exactly in proportion to the change in relative humidity. This type of instrument is more serviceable in very cold weather than the psychrometer. *See* pp. 7 and 8.

The Pressure of Wind. The pressure of wind as one feels it fanning the face or in the struggle against the gale, increases in a ratio very much more rapid than the increase in miles per hour. Mathematically it is reckoned in the ratio of the square of the velocity. For example, the pressure exerted by a 10-mile breeze as compared with a 50-mile gale is not as 10 to 50 but as 100 to 2500, which are the squares of the velocities. Thus, in breasting a gale a person receives 25 times as great an impact as that of a 10 mile breeze which is sufficient to snap out a flag flying from a pole.

The pressure of a 10-mile breeze at ordinary air density is only 0.27 pounds to the square foot, while that of the strong gale is nearly 7 pounds. The average adult, garbed for out-of-doors when a gale is blowing, presents a considerable area to its violence, and a great force smites him. No wonder the natural impulse is to turn the shoulder to the blast and reduce the area against which the pressure can act. Wind pressure also varies with the nature of the air itself; the icy gale of winter is heavier and exerts a greater force than one of equal velocity in summer.

Measuring Humidity. The dampness, or relative humidity of air, may be determined in several ways. One method is to find the difference in the temperatures recorded by an ordinary dry-bulb

thermometer and one with a bulb thinly wrapped in wet muslin. Both thermometers are fanned or whirled in the air together. The drier the air the more rapid will be the evaporation and the lower will be the reading of the wet thermometer compared with that of the other. If a clean fog is forming no evaporation will take place and the two thermometers will usually read alike. Then we say the relative humidity is 100 per cent.

In cold weather when the temperature is below freezing, this method of measuring humidity is unsatisfactory because the wet cloth around the thermometer may or may not freeze.

This difficulty may be readily avoided by the use of a hair hygrometer. The hair hygrometer is essentially a bundle of oil-free human hair so fastened that its changes of length are shown by the movement of an indicator. The Weather Bureau has recording hair hygrometers, called hygrographs, at many stations. As dampness increases, the hairs lengthen almost in exact proportion to the percentage change in relative humidity.

Differences Between Thermometers. Why do thermometers show such different temperatures? It is a question both of exposure and of the instrument used. If you hang two ordinary thermometers side by side probably their readings will not

be the same. Cheap thermometers are often inaccurate; the tube containing the mercury may be of varying diameter or it may be insecurely fastened to a backboard which bears the scale. In the latter case, if the thermometer is jarred, the tube may slide up or down, displacing the reading several degrees. A good thermometer always has the scale etched on the glass. Sometimes, when the column of mercury in a thermometer contracts, it separates, leaving a small portion in the upper part of the tube, thus making the thermometer read too low. Thermometers containing colored alcohol will give too low a reading also if part of the alcohol column evaporates into the upper part of the tube. For this reason, alcohol thermometers are not very satisfactory for observing high temperatures.

How to Take the Temperature of the Air. The air in general is warmed a little by direct sunlight, but mainly by the earth's surface, which in turn is heated by the sun. Some parts of the surface absorb heat readily and become much hotter than others. For instance, on June 18, 1918, a dirt parade ground in Texas reached a temperature of 141° F. while the temperature of adjoining grass was 112° and the air temperature 101°. Similarly, a screen of foliage will not become nearly so hot as a brick wall or a tar roof. In fact, the rela-

tive coolness of the foliage is largely the result of cooling by transpiration.

If we place our thermometer close to one of these heaters of the air, especially in a place where there is no breeze, we fail to get a correct average air temperature, just as we would get a wrong idea of the general temperature of a room if we hung our thermometer directly over a radiator. Again, if we place our thermometer in the sun it will absorb more heat from the sunlight than the air does, and will therefore become hotter than the air. Thus a thermometer with a large black bulb exposed to the sun may register 120° F. though the air temperature is only 50°.

There is a way of observing air temperature accurately, even in full sunshine, and that is by swinging, whirling or fanning the thermometer vigorously, and by this means bringing so many molecules of atmospheric gases into contact with the bulb that the effect of direct heating by surroundings is reduced to a minimum. Even by such a method an open space should be chosen to avoid obtaining temperatures of warm or cold pockets of air.

How to Measure Snow. The measurement of snowfall, especially in terms of rainfall, is of enormous importance in some regions of America where much of the winter's precipitation is held

fast till spring. Everywhere snowfall is of considerable interest. Its measurement is one of the most difficult of the usual meteorological observations, and great care is required for reasonably satisfactory results. Instructions for the nearly 6000 observers of the United States and Canadian weather services include three measurements in connection with snowfall: depth of each snowfall, water content of each snowfall, and total depth of snow on the ground.

In level regions where the snow is not much disturbed by the wind the observer has a relatively easy time, for he has but to use his measuring stick in a dozen or more places, or observe the scale reading of a previously carefully placed snowstake. R. E. Horton, of Albany, N. Y., has devised a snowboard for ready measurements of each snowfall. This is merely a thin board covered with white cloth, which he lays on top of the old snow. The rain equivalent is readily obtained after snows with which there has been no wind merely by measuring or weighing and computing the water in the snow that fell into the rain or snow gage. If wind has swirled snow out of the gage several vertical sections of the new snow may be cut from places where the depth is average, and carefully weighed. Where the snow is very deep, small, tubular snow-samplers are used.

SECTION II

EARLY SPRING

Water in Snow Accumulations. It is often of interest to determine the amount of stored water which a snow accumulation represents. Shall we expect floods or low reservoirs? Particularly on western watersheds, where snow furnishes the water for irrigation, snow surveys are of value. To find the water content of snow it is not sufficient merely to measure the depth. It may require as much as 17 inches of dry, loosely packed snow from the top of a deep drift to make 1 inch of water, while 4 inches of compact, moist snow at the bottom of the same drift, will give an equal amount. On the average, 10 or 12 inches of newly fallen snow will contain about 1 inch of water. Old snow found on the ground in the spring may be as much as half water, so that 2 inches will be the equivalent of a 1-inch layer of water.

The water content of snow on the ground is usually ascertained by cutting sections out of the snow from top to bottom and weighing the snow thus obtained. Every spring careful weighings of snow sections are made at key stations on

most large western watersheds and at some eastern stations. One can then compute total water supply represented by the snow, and the weather and flood forecaster by watching the temperatures, can tell how fast the water will become available.

Snow Blanket Allows Ground to Thaw. As the winter grows old the snow blanket permits the frost to come out of the ground beneath it, even while the soil of exposed ground remains solid. The snow acts as an efficient insulator to keep in the heat which is escaping to the surface from lower ground levels, and this heat serves to melt the frost, so that after a long period of snow-covered earth we find at the final melting that there is no frost whatever in the ground.

This absence of frost has an important influence in preventing spring floods. The water of the snow melting in the warm sunshine of approaching spring is absorbed freely into the soil. As a result pastures and lawns may emerge from the snow cover verdant with young grass.

This action of the snow is not well understood, even by many of the amateur meteorologists who delight in prophecy. It combines with other influences, especially the action of the snowfields in maintaining cold air over them, thus deflecting storms southward, to prevent what otherwise

would be devastating spring floods. In March, 1916, when the northeast lay buried deep in snow a local weather seer gave public warning of dangerous floods, and offered his own hill as a refuge to the fleeing people, as he pictured them. But when the final melting came, there was no flood. Instead, the countryside was exposed, fresh and green, its soil stored deep with the waters of the snow which had covered it.

Spring Sunshine in Late Winter. It seems rather odd that in many regions of the United States the strongest sunlight is experienced in February—a month surpassed for cold only by January. North of latitude 40° the maximum intensity may not come until March. In January we are nearest to the sun and so might expect the most intense sunlight, but the obliqueness of the rays decreases the amount of light received. When the sun is low, the rays must pass through a much greater thickness of atmosphere.

Thus, figures for Washington, D. C., show that if 1 represents the air-mass which would be traversed by perpendicular rays, 2 is the air-mass traversed when the sun is 30° above the horizon, 3 the figure for 19°, and 5 for 11°. The intensity of sunlight is measured on a surface perpendicular to the rays. At latitude 42° N. in the eastern United States this intensity increases 11 per cent

from January 21st to February 21st, remains about the same in March and then gradually decreases, reaching a minimum in December. The greatest change is from January to February. Not only is the sunlight brighter, but there are more hours of sunshine; for, while along the Atlantic coast January has an average of 4 to 5 hours of sunshine daily, February enjoys about 6. In each case this is about half the amount of sunlight possible were there no clouds. In February, then, we find sunlight an important factor in the melting of snow, and notice the disappearance of a snow cover and the awakening of plants first on southern slopes.

Blackened Snow Melts Fast. The fact that dark colors absorb the heat of the sun while light colors reflect it, thus permitting a surface to remain cool, is put to good use in the Sierra Nevada Mountains. In the spring the highways of the high passes are buried deep in accumulations of snow, sometimes even to a depth of 30 feet, and the normal rate of evaporation is so slow that automobile traffic is seriously delayed until long after roads at lower levels are open. It has sometimes required weeks to melt and break a way through. The railroads escape this because the tracks pass through snowsheds.

Then some bright mind conceived the idea of

scattering black soil and dark-colored ashes over the snow surface. It worked beautifully; the snow went almost magically fast as compared with previous experience, and interference with traffic was greatly shortened.

For the same reason old snow surfaces melt much more rapidly than new, particularly in the cities where the surface becomes coated with soot and dust. Communities where soft coal is generally used experience this in its most intensive form. As a consequence, lawns of parks and residences reveal themselves much earlier than do the pastures and fields of the surrounding country.

Evaporation of Snow. In the Great Basin of the western United States where snow furnishes the water for irrigation it is particularly desirable to know how much of the winter snow cover will be lost by evaporation. The Utah Forest Experiment Station, on studying this question in the winter of 1915-16, found that that season about 14 per cent of the total snowfall, or an amount equivalent to 3 inches of water, evaporated. In central Greenland, Dr. Quervain estimated that the loss from evaporation was about two inches of water per year, while R. E. Horton near Albany found an evaporation rate as high as one inch of water per month.

Temperature, wind and humidity, all control evaporation of snow. The Utah experiments indicated that, on the average, snow evaporated about twice as fast at 32° F. as at 20° F., while at 45° F. the evaporation was three times that at 32° F. Increase in wind velocity also tends markedly to increase evaporation from a snow cover, and the drier the air, the greater will be evaporation. But if the dewpoint is higher than the temperature of the snow surface evaporation may become a minus quantity. That is, moisture will condense from the air onto the snow surface. It was found in the Utah experiments that evaporation was generally more rapid in the daytime than at night, for sunlight and a lower humidity offset the slightly greater wind velocity at night. The effect of a forest cover on snow evaporation is somewhat uncertain. A forest offers some shelter from heavy winds; but trees, on the other hand, conifers, particularly, increase the evaporating surface by holding the snow on their branches.

Rain Melts Little Snow. When the old winter snow is still lying on the ground a characteristic spring rain has a temperature probably of not over 50° F. It can be shown that it requires 1 inch of rain at this temperature to melt enough

ice or snow to make ⅛ inch of water. Snow always contains much air; even dense old snow may be assumed to be half water and half air. So it follows that the 1 inch of spring rain, with a temperature of 50°, will melt about ¼ inch of snow cover.

But during such a rain accompanied by a good wind it is often apparent that the snow is disappearing very rapidly. Conduction from the wind itself, although the air temperature may be lower than that of the rain, will warm and melt some snow. A more important cause of melting, however, when the wind is warm and humid, is condensation on the snow surface of moisture from the wind. This occurs when the dewpoint of the wind is above freezing. When condensation occurs heat is liberated, so much in fact that the condensation of 1/30 of an inch on the snow surface would be sufficient to melt ¼ inch of snow, or as much as was melted by a whole inch of rainfall.

Heating of Land Surfaces. The surface of land heats and cools very readily, and its temperature reaches greater extremes than either air or water temperatures. Land surfaces do not store much heat; what heat the ground receives is almost immediately returned to the air or to space. Different kinds of land surface show widely varying temperature characteristics. In the first place,

Fig. 7. Coöperative Station, U. S. Weather Bureau. The white, louvered shelter a few feet over sod provides an excellent means for obtaining the air temperature in the open. The double roof prevents overheating in the sun, the louvered sides shut out the sun and most of the rain, and the sod does not become unduly heated and send much radiation into the shelter. Free passage of air through the sides ensures a temperature inside the shelter very nearly the same as that outside. The thermometers indicate the highest and lowest temperatures since last setting. The rain-gage on the right is high enough above the ground to avoid in-splashing, yet not so high that the wind usually makes strong eddies around its top. *See* pp. 9 and 10.

Fig. 8. Dew on a Spider's Web. Such a delicate beaded arrangement would be impossible if dew "fell."

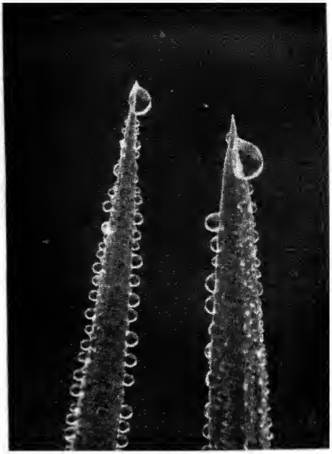


Fig. 9. Dew on Grass Blades. Some of the dew on green grass comes from moisture exuded by the grass itself.

Fig. 10. Dew on a Strawberry Leaf. Note how the droplets might roll down the inside of the leaf and down the stem. (Photos by W. A. Bentley, Jericho, Vt.) *See* pp. 27 and 28.

we can note differences in reflecting power; the white, smooth surface will reflect more radiation, and have a smaller range of temperature than the black, rough surface.

Relative dryness is an important feature. If moisture is present, part of the heat received will be spent in evaporating the moisture instead of raising the temperature of the ground. Measurements in Finland on some bright August days showed that a granite surface lost no heat in evaporation, a sand surface 20 per cent of the heat received, and a swampy meadow consumed 50 per cent in evaporation alone. In consequence, the granite was the hottest and the meadow the coldest. Moist surfaces also tend to heat more slowly than dry because of the high specific heat of water, that is, it requires more heat to warm a given weight of water 1 degree F. than to warm equally the same amount of almost any other substance.

Conductive differences are also very important in controlling ground temperatures. Only the surface layer of the ground is directly heated by radiation, the lower layers are warmed more or less according to whether the substance conducts heat well, or poorly. Granite will heat to a greater depth than sand and so will store more heat and remain warmer at night. So poorly does sand

conduct heat that while at a desert station a daily range of 49 degrees F. was observed at the surface, at a depth of 16 inches the change from day to night was only 1 degree F. Snow contains so much air that it is even a worse conductor than sand. A snow cover acts like a layer of sand two or three times as thick. Vegetation, similarly, acts as an insulator. Observations show that vegetation may cut to 2/3 the annual heat exchange of bare ground.

The Heat Budget of the Ground. The surface of the ground is constantly both receiving and giving off heat. Whether the ground temperature rises or falls depends upon how the budget balances, whether receipts or expenditures are in the excess. The sources of the income, or heat received, are the direct radiation from the sun and also the radiation from the air itself. Under ordinary conditions in summer the heat received from the atmosphere is easily more than 20 per cent of the heat received directly from the sun. The ground, in return, is constantly expending its heat, largely by radiation into space, but also by conduction both upwards and downwards. That is, the ground surface loses heat by coming in direct contact with cooler air above and cooler, deeper layers of soil or rock below. The ground also expends heat in evaporating moisture. The great-

est exchanges of heat occur when we have dry air, bright sunny days, and calm, clear nights, since radiation increases as the fourth power of the absolute temperature. Moisture in the air reduces the ground's net loss of heat by radiation. Clouds at night keep the earth warmer by sending more radiation to the ground, thereby diminishing the relative loss of heat.

The Lion and the Lamb. Though one cannot credit the old forecast that if "March comes in like a lion it will go out like a lamb," and vice-versa, one can readily grant the resemblance of March to both the animals. March is the storm-iest month of the year in the northern hemisphere, hence certainly at times a roaring lion. In March the Arctic regions have reached their lowest tem-perature. The sun is just starting to rise there, while the south, on the other hand, is warming rapidly. The sun is overhead at the equator about the 21st. These great temperature differ-ences strengthen the general circulation of the atmosphere, and favor storminess and high, roar-ing winds. But, though the house may rattle and creak in the gale one day, before long a warm, sunny interval full of spring promise will ban-ish the lion and introduce March in the rôle of the lamb.

SECTION III

MOISTURE IN THE AIR

Dry Air is Thirsty Air. Dry air is always thirsty. It eagerly absorbs into itself the free moisture of any surface with which it comes into contact. The warmer the evaporating surface the more readily will the water fly off into the air. The more humid the air the less rapidly will it permit water to evaporate.

In meteorology the amount of water present relative to the maximum possible for the temperature is known as relative humidity. For example, if air includes half as much as is possible at a given temperature, its relative humidity is 50 per cent. On a muggy day it may be 60 to 80 per cent. On a "good drying day," as the housewife calls it, when washing hung out on the line dries quickly, the relative humidity is usually low, sometimes down to 30 per cent in the warmest hours of the day. When it is high, clothes dry but slowly except in warm weather. Evaporation is usually more rapid in warm than in cool weather, because in any given volume more water can exist in a

vapor state at a high temperature than at a low one. Moist surfaces are always tending to discharge moisture into the air by evaporation, while cooling processes are always tending to dry the air by precipitating moisture out of it.

Plants as Outdoor Humidifiers. Plant life plays an important part in weather by assisting in the evaporation of moisture into the atmosphere. The process of releasing moisture through the pores of foliage into the vaporous state is known as transpiration. The roots take up the water from the soil, and it is forced up through the plant structure into the leaves, the surfaces of which have myriads of openings that permit the moisture to escape.

Plants evaporate more water than does bare ground, and constitute a better humidifier. It has been demonstrated that under certain conditions a leaf of corn gives forth one-third as much moisture as an equal area of free water surface, such as that of a pond. Corn on days of extreme heat will transpire as much as 10 pounds of water to a single plant. Of course, there is a great difference between the evaporating power in different plant species. Some give forth moisture freely, as alfalfa, some very slowly, as the olive. The rapidity of plant evaporation varies in the same manner as evaporation from earth and water

surfaces, according to the temperature of the surface, the wind velocity, and the humidity.

Sidewalks Dry in Drizzle. A dry sidewalk while the air is full of drizzling rain is not an uncommon sight. The reason is that the surface is warm from previous heating or from sunlight which penetrates the clouds, even while they are dense enough to give forth a drizzle. In the case of cement the heating may be also by conduction from below. In either case, or in the combination of the two causes, the surface is sufficiently warm to evaporate the moisture as fast as it falls and leave the sidewalk dry.

Clouds, of course, do not shut off all sunlight. One can be badly sunburned on a cloudy day, though not when clouds are dense enough to produce a drizzle. The occurrence of a drizzle is often an indicator of clear skies above, which, during the night, have allowed a lower moist layer of air to cool below its dewpoint, and so to form the thin clouds from which the drizzle falls.

There is Water in the Air. All the lower atmosphere consists in part of moisture. The warmer the air, the greater, usually, this proportion. For each temperature there is a limit to the amount of water vapor that can exist in any volume. Therefore, when warm air is cooled there must come a point at which some of the water

vapor must separate out, or condensation take place. The temperature at which this phenomenon occurs is known as the dewpoint. The importance of the dewpoint in weather science is evident when one considers that only when this temperature is reached does the condensation of atmospheric moisture take place in the form of dew, fog or cloud.

The number of degrees which the temperature must fall before the dewpoint is reached depends upon the humidity. If the air contains close to the maximum possible amount of water vapor at the existing temperature, then the dewpoint will be quickly reached. If the air is relatively dry, then the temperature fall must be greater if condensation is to take place.

For example, on a May morning when a column of heated air rises from the earth's surface it is cooled by expansion until, finally, its temperature is reduced to the dewpoint, and the condensation of some of its moisture forms clouds. If the warm column consists of highly moist air the temperature drop required is only a few degrees and the dewpoint will be reached at no considerable height. If the air is dry the ascending current will have to rise higher before clouds are formed.

Air Dries by Heating. To emphasize the meaning of dewpoint let us consider what happens in

a furnace-heated house on a foggy day in spring. The moisture-laden air is sucked into the furnace from out-of-doors, and is heated and delivered to the rooms above. It has become dry air. It has not left its moisture in the furnace chamber, but because of the high temperature the moisture can now exist as an invisible part of the air. On the other hand, were this same air returned immediately through a window to the out-of-doors the moisture would again condense in much the same form as it existed before it entered the house. In the furnace the temperature rose above the dew-point, but were the warmed air returned to the open it would quickly fall again below the dew-point.

Another illustration is what takes place when one fills a bathtub on a cool night. The air in the room is clear and warm, the window panes are free of moisture. Hot water flowing into the tub releases additional moisture into the air, thus raising the dewpoint, until at the temperature of the window glass condensation begins to take place and the window "sweats."

Still another illustration is that of a room which has remained unheated in cold weather. Everything is damp. The air has been cooled below its dewpoint and its moisture has condensed on furniture and walls and fabrics. With windows and

doors closed to prevent the escape of air a radiator is turned on, and presently the room is warm. Dampness disappears. We say we have dried out the room. Yet all of the moisture which had been felt as dampness is still present. It exists as a part of the heated air because the temperature is above the dewpoint.

Dew Never Falls. One sometimes reads of "falling dew." But dew never falls, except by dripping off roofs and leaves. It must form at the point where it is found. When night comes the earth loses more heat through radiation into the atmosphere than it gets back from the sky and this net loss is especially great on still and cloudless nights. Under these conditions the temperature of the ground and everything upon it falls sharply, and with it, though to a lesser degree, the temperature of the air above.

Dew begins to form on one object after another as the temperature of each falls below the dewpoint of the air in contact with it, just as a film of moisture forms on the outside of a glass of ice-water in summer. Light objects insulated from the ground by a layer of air are the first to reach the dewpoint, especially those like green leaves and blades of grass, which have abundantly supplied the air about them with moisture during the day, raising the dewpoint in their vicinity.

If the night be cloudy, the clouds radiate heat back to the earth and therefore objects seldom become cool enough for the formation of dew. Wind continually blows fresh air against the leaves and other objects, keeping them nearly as warm as the air, at a temperature above the dew-point.

Dust is All Important. Dust is an unpleasant and unwholesome substance to have about the home or street, but in the atmosphere it is indispensable. Without it there would be vastly less rain and snow. Moisture would not condense readily, because it cannot condense without something to condense upon. The nucleus of practically every droplet of water which enters into the formation of a raindrop is a particle of dust. The snowflake, also, is usually dependent upon a dust nucleus. Experimentally it has been found that moisture will condense in dust-free air, but only at extremes of super-saturation rarely, if ever, occurring in nature.

Therefore, it is fortunate that the atmosphere, no matter how clear it may be, usually contains vast numbers of dust particles. They help to make the sky blue, though the air molecules are mainly responsible for this color, and they play an exceedingly important part in the creation of

wonderful sunset colors, particularly the reds and yellows; for their presence in the atmosphere, with or without adhering molecules of water, tends to scatter or absorb, and destroy to human sight, all but these colors of long wave length.

SECTION IV

CLOUDS

Watch the Clouds. Get well acquainted with clouds, for in knowledge of the weather they play the leading rôle. The best known, and probably the best liked, because it is usually associated with pleasant days, is the cumulus, detached, clean-cut, having a flat base, billowy, the illuminated portions snowy white, the shaded parts usually dark. This is the cloud with the silver lining. When the atmosphere is dry the cumuli are the fair weather clouds, sailing along serenely, perhaps a mile high in the sky, sometimes widely separated one from another, sometimes in packs. But in muggy weather they are the nuclei of the towering thunderheads, which are as menacing as they are beautiful.

The stratus clouds are low, and flat, and foglike, and of wide extent. They often merge into a third general type, the ragged, gloomy nimbus, from which rain or snow is falling. The fourth general class is the cirrus, highest of all clouds, of strange wispy forms. They appeal strongly to the imagination; their speed is so prodigious, their temper-

ature lower than anything on earth, their distance up in the firmament so great, and their portent of storm so significant.

Mare's-tails Are Cirrus Clouds. An intimate acquaintance with the cirrus clouds, and their close relatives, the cirro-stratus and cirro-cumulus, is most useful in recognizing approaching stormy weather. Even in the hottest weather they consist of ice-needles because they are usually from 3 to 6 miles above the earth, where the temperature ranges from 15 to 100 degrees F. below freezing.

Usually they appear as the advance guard of a storm, which their great speed causes them to outstrip, though they had their origin in the same place and at the same time as the rest of the storm mass. The true cirrus is first to arrive. The name is most appropriate; translated, it is "a curl," "a ringlet." Its "Mare's-tails" are like long wisps of hair, its "feather clouds" are great curling plumes.

As the storm gets nearer, the cirro-stratus clouds appear, a thicker layer like an unbroken white veil, of uneven and often fibrous texture. Their tops are of about the same altitude as the cirrus, but their snowy trails have fallen lower. Cirro-cumulus may accompany them as thin whitish flocks from which the cirrus snow trails fall.

In the most familiar form it is the "curdled sky." More picturesque still is the mackerel sky where the clouds are arranged in groups and lines very like the pattern of the fish's back.

Mackerel sky and mare's-tails
Make tall ships carry low sails.

Clouds as Wind Indicators. The clouds play an important part as indicators of the direction and speed of winds aloft. When the aviator or meteorologist wants to know conditions in the free air he may send up a pilot balloon and watch it travel as it rises; which does very well in a clear atmosphere, but is useless as soon as it disappears in a cloud. Or he may simply watch cloud motions.

A cloud, being merely an aggregate of liquid or solid particles, usually travels with the same speed and direction as the wind at its level. Rising thunderheads and the cumulus cloud in its early stages are exceptions since their air has just come from lower, slower levels. So also is the well-defined lenticular cloud, often called crest cloud, banner cloud, or billow cloud, which marks the standing crest of a wave when air is streaming over an obstruction, such as a mountain range. With these exceptions, clouds indicate the winds.

But from the angular motions of clouds, which

alone usually are observable, actual speeds are not obtainable unless their distances are known. Rarely can a single observer establish the height, excepting in the case of clouds formed from air recently at the ground level, or such clouds as show city lights or intercept searchlight beams at a known distance. When cumulus clouds pierce several cloud layers it is a simple matter to get the relative heights of the layers and from a computed height of the cumulus base find the actual heights. Pilot balloon and cloud observations in conjunction give the most satisfactory results; for the balloon can be used to find the cloud heights as well as to indicate the winds at the cloudless levels.

Airplane Betters Cloud Record. Until some months ago the speed of lofty cirrus clouds racing grandly across the spring sky seemed beyond human attainment. Their highest known rate is 230 miles an hour. American and French airplanes have now gone faster than that. They can outstrip any cloud in the sky.

In summer the average velocity of the cirrus in the northern United States is 60 miles an hour, in winter 90 miles. Seen from the ground their apparent motion is usually not rapid, just as the fastest flying airplane high above the earth appears to have no great velocity. They are far

away from the eye and there is nothing near them with which to compare the swiftness of their flight.

Velo Clouds. A summer phenomenon of the seacoast is the velo cloud, which, translated, is "the veil cloud." Locally it is known as "high fog." Such clouds drift in from sea and often, in the early morning, are seen at a few hundred feet above the ground. The coast of southern California has them frequently, and they are by no means uncommon along the Atlantic seaboard. Those persons who are not weatherwise sometimes mistake the velo for a rain cloud and look for a day of foul weather, only to see the cloud dissipated as the sun warms it.

In its original form the velo is sea fog of exceptional thickness, sometimes as much as 2,000 feet. When a warm moist air blows over the cold surface of water it may be cooled to below its dew-point, and some of its moisture is condensed as fog droplets. The fog does not lift to become the velo cloud. When it strikes the heated surface of the land its lower stratum is warmed to such an extent that its temperature rises above the dew-point, the droplets are evaporated into the air, and it disappears. But the upper stratum remains cool, and, being separated from the ground, thereby becomes a cloud.

The Lids of the Air. Wherever a layer of warm

FIG. 11. STRATUS CLOUDS AT TWO LEVELS. The lower sheet enshrouds some of the distant low hills. Such clouds are usually formed when a warm, moist wind begins to blow over cooler air near the ground. The dark clouds above mark contacts of the warmer south wind below, with cooler, more westerly winds above. Rain follows such a formation often within very few hours, and the temperature rises markedly. (Photo by A. J. Weed, Mt. Weather, Va.) *See* p. 30.

FIG. 12. CIRRUS CLOUDS (upper half) MERGING INTO CIRRO-STRATUS (lower half). These white snow trails in the sky usually blow far ahead of a general storm, and give a warning of 12 to 36 hours of the possibility of rain or snow. (Photo by A. J. Henry, Washington, D. C.) *See* pp. 30-32

air rests upon a layer of cool air a "lid" or "ceiling" is formed. It is more than a name: it is a tangible obstruction well known in aviation; for the airplane that passes through it may get a smart bump, and a lightly ballasted free balloon descending upon it may rebound and shoot upward several hundred feet. The reason for its formation is that the air masses of adjacent layers do not mix readily one with the other, unless there is a strong wind or powerful vertical currents. Smoke, dust, or cloud matter rising to the top of a stratum or sinking to the bottom, does not always penetrate, but spreads out laterally, forming stratus clouds. Under favoring conditions there may be a succession of lids in the atmosphere, one above another, each representing the top of a cool layer.

A low lid impairs visibility to a marked degree. An extreme illustration is the famous London fog, where the products of burning soft coal, held below the lid, produce a pall-like covering, through which the sunlight penetrates but little, thus producing the effect of night in the daytime. Not until increasing wind or general cooling breaks the lid is a clearing of the atmosphere effected.

Wind Clouds. After a rain it is not unusual for the sky to clear for an interval before the commonly following, cool, northerly wind becomes

established. If the early morning is clear the lower air heats rapidly till it becomes too light to stay under the cooler air above. Then masses of cool air descend and force the warm air to heights from several hundred to well over a thousand feet. The cooling, which the rising humid air experiences as it ascends and expands, condenses some of the moisture into the familiar cumulus clouds. These clouds grow upward till they have cooled to a temperature below that of the surrounding air and thus have become heavier. Within a few hours after the cool wind following a rain has begun to blow, the vertical extent of this cool wind is usually not greater than half a mile to a mile. Thus the cumulus clouds cannot grow much before they reach the lid of warm air at the top of the cool layer. Here they must stop cooling and stop rising and spread out in ominous masses of downward-bulged and ragged strato-cumulus cloud. But for the lid that stopped the upward progress and, therefore, the cooling, these clouds would have become shower clouds. Now, however, they are but wind clouds. The name "wind clouds" is very appropriate; for, the stronger the cool wind the greater is the overturning of the lower air that is responsible for the clouds, and the more pronounced is the contrast between the cool wind below and the warm air above, form-

ing the lid that prevents the clouds from rising high.

Billow Clouds. Billow clouds, sometimes called windrow clouds or wave clouds, are regularly spaced bands, shining white when the sun strikes them, with intervening strips of blue sky. They usually form in the lower cirrus region, three or four miles up in the air, but may form at any level, from that of surface fogs to the higher cirrus regions. They are caused by the flow of one layer of air over another of different temperature and density, and usually of different humidity.

Whenever two such strata meet, billows of great wave length and often of great amplitude are generated, in the same manner that wind produces ocean billows. As the waves advance the atmosphere rises and falls, producing maximum and minimum temperatures, that of the crests being lower than that of the troughs. If the ruffled layer is sufficiently humid the wave crests, being coldest, condense some of their water vapor as clouds, while the troughs, being warmer, remain clear, and through them we see the sky, thus obtaining the visual wave effect. If, however, the humidity is low, the wind billows exist without clouds and are invisible to the airman. He can avoid billow clouds, for he can see them and fly above or below. But he cannot avoid the invisible

except by chance, and once within the influence of the waves he experiences a series of disconcerting bumps, due to the quick transition from one billow to another, and sometimes he finds it difficult to rise out of them to a safer layer of air.

The Heights of Clouds. The question is often asked: How high are the clouds? Each type has its own range of altitude, dependent upon atmospheric conditions. In general each type is lower in winter than in summer, lower over humid regions than over deserts, and lower with increase in latitude. The higher the humidity of the air, the lower the cloud levels, because moisture-laden air does not have to ascend so high to reach its dewpoint and condense its vapor.

Fog is a cloud in contact with the ground. Next above is the scud region, from 300 to 1,000 feet up in the air, with its low-flying clouds which are seen under the raining nimbus clouds. The nimbus, formless, thick masses, from which rain is falling, have an average base altitude of 3/5 of a mile. The stratus is another low-flying cloud, foglike in character, often merging into a nimbus, and again clearing away like lifting fog. In some cases it is the velo cloud, which is originally a thick fog layer, the lower stratum of which has been dissipated by warming.

The beautiful, fleecy cumulus clouds are formed

at varying heights, their bases ranging in altitude from 2,000 to 4,000 or more feet, and their tops averaging perhaps twice as high. In their thunderstorm proportions, when they have become cumulo-nimbus clouds, their tops usually soar to a height of three or four miles, sometimes to seven or more miles.

The highest of all clouds, the cirrus and cirro-stratus, so high that they are of snow, even in summer, are found at levels from two to seven or more miles high. Clouds from intense volcanic eruptions have been observed at still greater heights, some in northern and central Europe about 50 miles high during the few years following the great Krakatoa explosion of 1883.

Air Cooled by Ascending. When air rises it is cooled in the process of expansion, which results from decreased atmospheric pressure. Conversely, descending air is warmed by compression, which follows increased pressure. When air expands it does work, so to speak, and in so doing loses its heat. When air is compressed work is done on it, which adds to its heat. A familiar illustration of this is in the bicycle pump which becomes quite hot when used vigorously in causing compression.

Under ordinary conditions the cooling of uniformly ascending air proceeds at a regular rate.

Technically, this is known as the adiabatic rate of change in temperature. For each 1,000 feet increase of height the temperature drops a little over 5 degrees Fahrenheit. Thus on a hot morning the air at a temperature of say 80° F. at the ground, impelled aloft in ascending currents, would fall about 16 degrees, to 64°, at an elevation of 3,000 feet. If the dewpoint of the air were as high as 64°, condensation would begin, at the level of 3,000 feet, and clouds would form. In fact, it is chiefly because of this process of cooling by expansion that clouds form and give us rain or snow.

Expanding Air Forms Clouds. On a bright, pleasant morning the air near the ground, cooled in the night, soon begins to warm under the influence of the sunshine. Naturally, within a given area the heating is more rapid in some places than in others. Over an open pasture, for example, it would be quicker than over a tract of woodland. As the air is heated it expands, and presently these lighter masses are forced upward by the cooler, denser air about them, all the time expanding as they ascend, and cooling as they expand. Finally, the columns reach a height at which the cooling has brought the air to its dewpoint and vapor condenses as clouds.

On a muggy summer morning clouds may be

seen forming as fleecy, white puffs above the smoky outpourings of factory chimneys, whose heat has caused the first of the ascending air columns. Were air visible we should see this vertical circulation, with currents ascending and, in some places, currents descending. On a hot, muggy day this action becomes violent and the currents travel at great speed. The turbulence hurls the moist air high above the cloud base, and thunderstorm conditions are created.

The phenomenon is known as convection, which is a common word in technical discussion of the weather. In some form it is the cause of the great majority of clouds. A similar phenomenon occurs when a warm, moist wind encounters a range of mountains and is deflected upward. The same cooling process takes place, which is the reason that rainfall on mountain ranges, especially on windward slopes, is far greater than on the plains and valleys about them.

How the Cumulus Cloud Stays Up. People have often puzzled over the question of how clouds remain aloft. In *Modern Painters,* in the section *Of Cloud Beauty,* Ruskin discussed this question, and could explain the floating of clouds only by assuming their particles to be "hollow spherical globules . . . in which the enclosed vacuity just balanced the enclosing water." We now know that

clouds are not composed of any such curious globules, but are aggregates of solid or liquid particles and really do not "float" at all but are constantly tending to fall. Gravity may be overbalanced, however, by other forces. For example, a cumulus cloud is supported by the strength of the ascending air current of which it marks the top. The stronger the local convection, the stronger are these up-and-down vertical currents. An aviator flying in such conditions finds the air "bumpy"; his plane may be suddenly borne aloft with an ascending column of air, or, entering a return down current, he may drop as if into a hole. If a convectional current ceases suddenly, a cumulus cloud at its top may start to fall, but will probably evaporate quickly and disappear. In the case of particularly strong convection where large drops have been held aloft, some may fall far enough to reach the earth as rain as the cloud disappears, giving us the peculiar experience of a light shower from an apparently clear sky overhead.

Clouds Do Not Float. While the cumulus cloud is held up by a vertical air current, other types of clouds remain aloft in other ways. Clouds do not float; their particles are always tending to fall. The larger drops or crystals will fall more rapidly because they have greater weight in pro-

portion to their surface, and so encounter relatively less friction in falling through the air.

Observe a high cirrus cloud, one of the delicate streamers marking the edge of an advancing cloud sheet. Such a cloud is typically curled slightly, like a feather. The larger snow particles are dropping out of the advancing higher portion, making a long trail behind, usually in the direction from which the cloud is moving, and finally evaporating. Blurry masses of snow or rain may sometimes be seen dropping from a stationary lens-shaped cloud of water droplets. As long as conditions continue to favor condensation, the cloud will keep forming and replacing the particles that drop out. Similar is the case of a cloud on the boundary between a cold wind, and a moist, warm one. The droplets keep settling gradually, either evaporating, or producing rain, but as long as condensation is maintained along the line of contact, the cloud keeps forming and so appears to remain aloft.

The Ragged Fracto-Cumulus. Occasionally of a summer afternoon we see the beautiful cumulus clouds begin to disintegrate as they sail along in the blue sky. Their clean-cut, rounded, upper edges begin to wisp out, torn by the wind. Their bases are no longer the sharp-drawn, horizontal lines. They cease to be the cumulus, and become

what the meteorologists call fracto-cumulus, a name descriptive enough in itself to require no explanation.

A chief reason for the breaking up of the cumulus cloud is the dissipation of the warm air masses whose original upthrust formed the cloud. With cessation of upward motion, the cool cloud falls back, is warmed by compression, and is thinned into ragged form, and dissipated.

SECTION V

WIND AND WEATHER

What Wind Is. Wind is simply air in motion. Air moves because of horizontal differences in atmospheric pressure, which result directly or indirectly from contrasts in temperature. Wind velocity, as measured, for example, in miles per hour, depends principally on the pressure gradient, the air density, the latitude, and the friction. In any locality the pressure gradient at a certain time is the horizontal rate of change of pressure in the direction in which this rate is greatest. The greater the difference in pressure in a given distance, the steeper is the gradient; and the steeper the gradient the swifter will the air flow as wind, just as the speed of a stream depends upon the steepness of its fall. Air density is a factor, for the denser the air the less rapidly will it flow with a certain pressure gradient. Latitude is involved in wind velocity, for it is a factor in the deflective effect of the earth's rotation, which is operative on all winds except those on the Equator. Friction, of course, retards the flow of air, to a greater degree over land, and to a less degree over water.

The atmosphere always has its moving high and low places, as measured by the barometer, which, for sake of illustration only, may be compared with differences in elevations of the earth's surface. Air always tends to flow from a region of high pressure toward one of low pressure, just as water flows from highland to lowland. In the case of air, however, this flow is usually very indirect, because of deflection as the earth rotates. With both air and water, gravity is constantly tending to create a state of equilibrium.

Eclipse Weather. When the moon shuts off the sunlight or part of it for a few minutes it has the effect of a great cloud suddenly spread over a wide region. The air temperature begins falling as the sun becomes even partially obscured, and during a total eclipse becomes several degrees lower than before or after. This lowering of the temperature contracts the air, and results in a slight inflow from the surrounding unshaded areas, which, however, is not easily detected. Careful observations on both sides of the path of a total eclipse have been required to establish that there is this inflow of air. The air does not, however, flow straight but goes in spirally, for after the air starts to move and before it can reach the center of greatest cooling the earth has turned a little under the moving air so that it misses the

center, going to the right of it in the northern hemisphere. Furthermore, the shadow of the moon, or center of greatest cooling, is itself moving rapidly. The air from both sides misses the center, and thus forms what is called the "eclipse cyclone" even though it is made of very weak winds. The eclipse cyclone is of particular theoretical interest because, unlike most spirally inflowing systems of air, the center is cooler rather than warmer than the surroundings. Other effects of the cooling are to cause any sheet clouds which may exist to grow denser for the time being, and to stop the formation of cumulus clouds.

Our Winds Turn to the Right. Wind in the northern hemisphere is constantly tending to swerve to the right. Let it start from the north headed directly south and presently it becomes a northeast wind. Let it start as a west wind, and in turn it is a northwest wind. The reason is that the earth rotates on its axis, and thus turns the cardinal points under the moving air. This turning is greatest at the poles, where it amounts to 360 degrees in a siderial day, that is, in the time it takes the earth to make a rotation to the same position with respect to the stars. Only at the equator does a north-south horizontal line not turn as the earth rotates.

Were the globe to cease its rotation, and were

its surface smooth, without mountains or valleys, the hot air of the tropics would overflow continuously straight poleward and the return current come straight equatorward beneath. In the northern hemisphere the wind aloft would be from the south, and at the surface from the north. There would be none of the deflecting force to produce the curved wind paths. The effect of the rotating motion is to cause all winds blowing in the northern hemisphere to curve off to the right, and all those of the southern hemisphere to go to the left of the direction in which gravity would send them.

A familiar instance of deflection of wind occurs in the sea breeze which visits the Atlantic seaboard on afternoons of very hot days. It is first felt coming directly from out to sea as the cool air from the ocean starts directly landward. Its beginning is but a short distance out to sea, and it has not traveled long enough to be much deflected. But as the breeze continues the air arriving having been in motion for longer and longer periods the direction veers more and more to the right.

The Procession of the Weather. Areas of high and low pressure pass across the United States in constant procession from west to east, at velocities averaging 20 miles an hour in summer and 30 miles in winter. In summer when the atmos-

pheric circulation is weaker the speed is slower and the contrasts between "highs" and "lows" are less pronounced than in the winter, for which reason weather is less changeable and disturbances, apart from thunderstorms and the infrequent tornado and hurricane, are less violent. Each high or low pressure area covers a great territory, ranging in diameter from a few hundred to a thousand or more miles.

In meteorology these areas are known as "highs" and "lows," and, when well-defined, "cyclones" and "anticyclones," names derived from their wind systems. Generally speaking, the "high" or "anticyclone" is an area of fair weather, the "low" or "cyclone" an area of stormy conditions.

The term "cyclone" was first applied to the storms of spirally inflowing winds about low pressure centers in the Indian Ocean, corresponding to our West Indian hurricanes. Then its usage was broadened to include similar though usually less violent storms in temperate latitudes, and also the small destructive whirlwind meteorologists call the tornado. The term "anticyclone" was invented to designate the spirally outflowing systems of winds from centers of high pressure.

A Useful Barometer Law. Stand with your back to the wind and the barometer will be lower

on your left hand, a little to the front, than on your right hand. This is what is known as Buys Ballot's law, which was established many years ago, and for years has served as a valuable aid to the mariner. By its use he can locate the center of low pressure in its relation to him. For example, if the wind is southeast, he knows that off to the west-southwest, on his left hand, but a little to the front of him, lies the storm center.

In this connection the rule of the United States Weather Bureau printed on its daily weather map should interest those who like to watch the wind direction. "When the wind sets in from points between south and southeast and the barometer falls steadily, a storm is approaching from the west or northwest, and its center will pass near or north of the observer within 12 to 24 hours, with wind shifting to northwest by way of southwest and west. When the wind sets in from points between east and northeast and the barometer falls steadily a storm is approaching from the south or southwest and its center will pass near or to the south or east of the observer within 12 to 24 hours, with wind shifting to northwest by way of north. The rapidity of the storm's approach and its intensity will be indicated by the rate and the amount of the fall in the barometer."

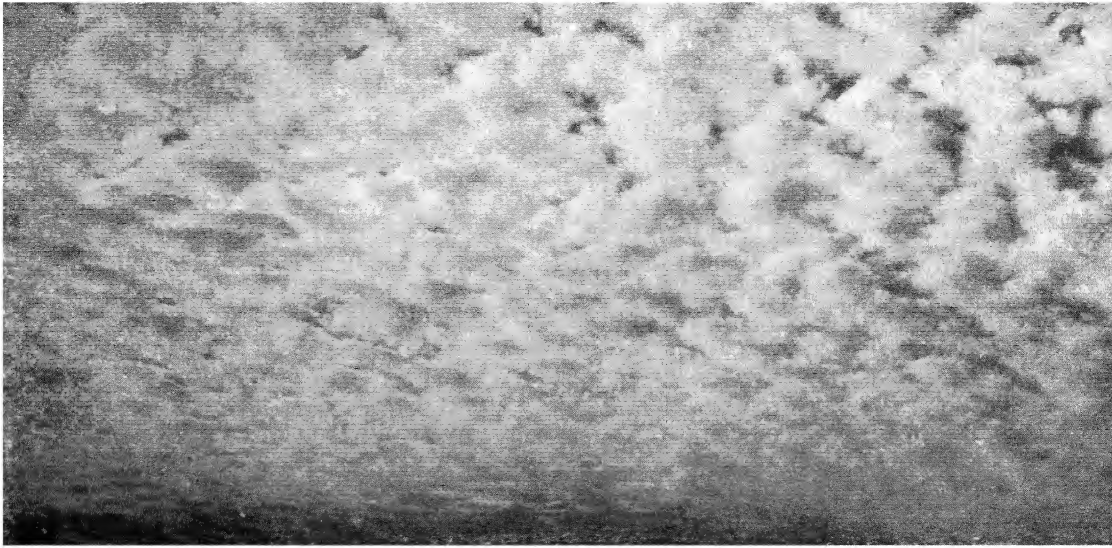


FIG. 13. ALTO-CUMULUS CLOUDS. Such clouds are formed characteristically where there is a layer of air appreciably warmer in its lower than in its upper portion. Under such conditions masses of the cooler, heavier air descend in many places and force upward numerous masses of the warmer, lighter air. When such warmer air is forced high enough the cooling by expansion becomes sufficient to condense some of the moisture into clouds. Alto-cumulus clouds when associated with higher, cirrus clouds often give warning of a storm. (Photo by A. J. Weed.) *See* p. 32.

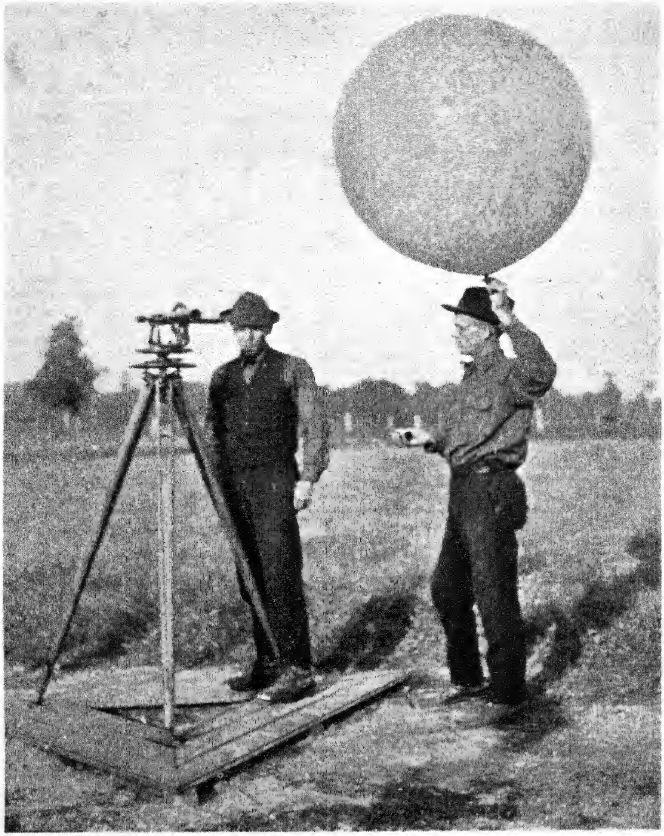


FIG. 14. THE BEGINNING OF A PILOT BALLOON RUN, U. S. WEATHER BUREAU. The fine rubber balloon is inflated with hydrogen to a point where it will rise at a rate of 200 meters in a minute. After release an angular altitude and direction reading is made every minute. From these successive observations the direction and speed of the wind at all elevations reached by the balloon are determined with fair accuracy till the balloon passes out of sight, or bursts. *See* p. 32.

Forecasting. The entertaining and useful practice of forecasting the weather began long before the days of weather bureaus; early rules evolved by the successful prophets have long been handed down in the form of weather proverbs. The first forecasting must have been empirical. For instance, without understanding the processes of condensation, people learned from experience to expect rain from heavy clouds. So we still say, sometimes mistakenly, "It looks like rain," while the scientific observer with instruments to aid him will feel more certain of his forecast if, in addition to noting the appearances of coming rain, he can observe a falling pressure and a rising relative humidity. When to local observations we can add a weather map showing distant conditions to assist us, we have reached the modern stage of forecasts. Local observations allow us only to surmise more distant conditions, which are accurately reported and mapped for Weather Bureau use.

Factors in Forecasting. In weather forecasting in middle latitudes, the motto is:

Eastward the course of the weather makes its way.

Weather men know that if a hot wave is in the Ohio Valley one morning it can be expected to

make the middle Atlantic coast swelter the next morning. And the cool wave appearing in Ontario promises relief in New England within 24 hours.

Also there is the rule that like attracts like. Big areas of clear and relatively cool weather tend to move toward other similar areas, known as areas of high pressure. Storm areas, or those of low pressure, tend to move toward other similar areas. As a rule, the northern latitudes experience chronic low pressure, and the latitudes of the southern border equally chronic high pressure. Storms moving eastward tend to veer to the north and the areas of clear, cool weather, to the south. Monthly maps of average tracks show the forecaster how great these tendencies usually are for "lows" and "highs" from any region and in any position.

The third big factor in forecasting weather is similar to one of the factors that makes a good doctor; knowledge of the personal peculiarities of the patient. Weather varies in character and behavior from season to season and over different areas of the country. Conditions which may bring fair weather in one section may cause rain not many miles away. Experience with the ways of the weather enables the professional forecaster to tell what is coming next, just as knowledge of the

patient helps a doctor to read his fever chart intelligently.

How to Use a Weather Map. There is no surer way to appreciate the difficulties of forecasting than to try a hand at the game. Take the daily weather map and make your own forecast. Each morning the map with its table shows what the weather was at 8 a.m., Eastern Standard Time, and summarizes the conditions of the preceding 24 hours.

If you wish to compete with the official forecaster first look at the weather situation to the northwest, west, or southwest of your location. From the size of an approaching rainy or fair area, one can see not only to some extent why the forecaster is likely to be right, but also what the weather may be after the period covered. Such simple approximate rules as the following may be helpful in using weather maps:

1. Weather moves generally from west to east in our latitudes, because the prevailing winds are in that direction.

2. High pressure areas are likely to move toward the southeast and low ones toward the northeast. The dense air of a "high" tends to spread continually southward under the warmer, lighter air of a "low" and to displace it northward.

3. A "low" tends to follow the direction of the

isotherm (equal temperature line), passing through its center. This is largely because winds aloft are about parallel to the surface isotherms.

4. Warm areas favor "lows," and cold areas, "highs." In winter "lows" tend to choose paths over the relatively warm Great Lakes and St. Lawrence Valley. Similarly, in winter the warm waters of the Gulf Stream and even the Gulf of Mexico, in spite of general high pressure in its latitudes, favor development and intensification of "lows," while the cold interior produces many "highs."

Making the Weather Map. One of the finest examples of efficient, instantaneous, and useful co-operation in the world to-day is the United States Weather Bureau. Twice each day, at 8 a.m. and 8 p.m., Eastern Standard Time, skilled weather observers at about 250 stations scattered over North America and the West Indies, telegraph in code to Washington just what the weather is with them—temperature, barometer reading, fair or cloudy, wind velocity and direction, precipitation as rain or snow—and at times other information.

At the district forecast centers of the Weather Bureau groups of highly trained men receive, chart, and interpret this information. One man reads the messages aloud as they arrive, decoding as he goes. Each of the others listens for his par-

ticular part of the message. Some write the figures direct on a great weather map, others quickly determine the changes since the last observations and enter them on secondary maps, still others set up a table of data. With the last message the maps are completed, the tables set up, almost ready to print.

The forecaster pictures to himself the probable weather changes for the next 24 and 36 hours, and then prepares his forecasts. While they are being set in type the isobars, lines of equal barometric pressure, and the isotherms, lines of equal temperature, rain areas, wind arrows, degree of cloudiness and thunderstorms are being transferred to two engraving stones, and the forecasts telegraphed to distributing stations, 1700 of them, all over the country. These stations, including many powerful radio broadcasting ones, immediately begin sending out the weather news by radio, telegraph, telephone, and mail to the sailors, farmers, market gardeners, fruit growers, stockmen, and every one else who is sufficiently interested to ask for the service or merely to listen in on the radio. The Weather Bureau sends out the forecast daily by mail to 100,000 places, and through them to 5,000,000 people.

The Forecaster's Vernacular. To follow intelli-

gently the daily forecasts of the Weather Bureau, a knowledge of the meaning of the vernacular is necessary. Few people fully understand it. When the forecast is "rain" it means any kind of precipitation in season, whether rain, snow, sleet or hail, though the forecaster will specify snow when he can. If the fall is less than one hundredth of an inch the forecast is considered to have failed. "Fair" means only the absence of precipitation. The forecaster differentiates as far as possible, however, between the kinds of fair weather expected, as "partly cloudy," "cloudy," "unsettled," "overcast," or "threatening," and he is correct if there is no rain measuring .01 inch. A sprinkle now and then does not vitiate his prophecy. The term "clearing" means that rain will probably fall during the early part of the time covered by the forecast.

When the forecast is "warmer" it means that the mercury will rise a certain number of degrees, varying for different seasons and different parts of the country, and similarly with "cooler." If no change is anticipated and the forecaster says "not much change," "continued warm," or "continued cool," it means there will be no appreciable variation up or down. The coming of a "cold wave" promises an amount of fall commonly considered as very much colder and to an unusually

low temperature, varying with season and locality. For the region extending from southern Maine to northern New Jersey on the coast and westwards to Nevada the drop in temperature during the winter months must be 20 degrees in 24 hours and to a minimum of 10° F. above zero or lower.

Unsettled Weather. Occasionally the weather forecast is "unsettled" weather, a condition which may last for several days. It arises when areas of high and low pressure are not well defined; a very weak "low" borders on an equally weak "high." Neither has the power to dominate the weather. They are moving across the country very slowly, so deliberately, in fact, that they may become stalled. There may be showers or there may not. The forecaster cannot tell, because the usually sharp definitions are not present. In hot weather local conditions may take control, through strong convection, which is the turbulent interchange of air between the warm moist lower levels and the cooler altitudes aloft. No dependence can be placed on its being fair, nor can one be certain that it will rain. Finally, well defined systems arrive, and the forecaster comes into his own again.

Storm Signals. Many people sometime during the 24 hours pass within view of a weather station,

where weather signals are shown, and to them a knowledge of what the signals tell should be interesting and useful. A square white flag means fair weather, a square dark blue flag, rain or snow. A square white flag with a black square in its center says that a cold wave is approaching. When the plain white flag has a dark blue triangular flag above it the prophecy is fair and warmer, but if the dark blue triangle is below, it means fair and colder. The blue triangle above the blue square flag means rain or snow and warmer, while flying below, it means rain or snow and colder. When instead of the white flag one with the upper half white and the lower half blue is displayed it indicates merely local showers of rain or snow. The triangular flag, if present above or below, indicates, as in the other cases, warmer or colder. A red triangle means that moderately strong winds may be expected. If you see a red flag with black center, prepare for a violent storm, and if two such flags snap in the wind beware the awful hurricane. At night a red lantern and a white lantern give warning of a violent storm. Two red lanterns, separated by a white lantern, tell the mariner to remain in harbor, for it warns of the hurricane.

SECTION VI

RAIN

Raindrop Forms on Dust. A raindrop consists of a considerable accumulation of water condensed upon a particle of dust in the air. As condensation continues, the globules of water first formed become larger and larger, and as they grow they begin to fall at an appreciable velocity. Some drops unite. Soon the larger drops fall fast enough to pass through the rising air which was responsible for the condensation, and, if they escape total evaporation in their descent, fall as rain.

A good-sized raindrop contains as much water as 8,000,000 ordinary cloud droplets. The ordinary drop is one-sixteenth of an inch in diameter, and the largest, one-fifth of an inch. The raindrop's size as it reaches the ground depends upon conditions. In gently rising air condensation takes place very slowly, and thus even very small drops can fall, and we have drizzling rain. Where convection is strongest, with powerful ascending air currents, drops may be held aloft until they are very large, the extremes falling with great

splashes, as observed just in advance of the downpour of a thunderstorm.

Rainclouds and Rain. Dark clouds always suggest rain. Even when there is nothing more than a dense pall of forest fire or city smoke, people carry their umbrellas or raincoats. There is ample justification for this, for usually when the daytime sky becomes dark, rain or snow follows. Furthermore, rain seldom falls except from a dense cloud. Therefore, the raincloud which weather observers the world over call nimbus is of this character, though not all dense clouds are nimbus.

The nimbus cloud is produced chiefly by the expansional cooling of rising air caused by the converging of air currents, by the upward deflection over land barriers or barriers of dense air, or by cold air underrunning warm air. The cooling which causes condensation often results, in part, from the mixing of warm air with cold, but chiefly from the expansion of warm air as it rises. In these ways, nimbus clouds are formed, to pour out their contents as rain.

A subdivision of the nimbus type is the fracto-nimbus, commonly called scud, a low, detached cloud, too thin and mist-like to produce rain, seen drifting beneath the heavy nimbus at an elevation of from 300 to 1000 feet. It is caused by the

turbulence of the surface wind cooled and moistened by the falling rain. On hill and mountain sides the nearly saturated warm air in the woods and valleys is forced up by the cooler air high enough to form the valley steam clouds, familiar to those who live in mountain country.

Rain Forms Where It Falls. The popular idea of rain or snow is that it arrives on the wind, ready made. In their mind's eye many people see the drops or flakes forming great distances away, usually out on the ocean, and carried by the storm-wind over sea and land until finally its time comes to fall. This is far from being the fact.

Rain or snow forms where it falls. For example, the cold northeast storm wind arrives, bringing little moisture with it. The moisture is already here, wafted up from the south in warm winds. Being warm and light the south wind rides above the cold air. Thus we have the northeast wind in the levels next the earth, with the south wind flowing over it aloft. The warm, moist air rising over the denser air hugging the ground is cooled by expansion so far that its dewpoint is reached. Further cooling condenses some of its water vapor, and we have rain in summer and rain or snow in winter.

In the great, northeast storm of October 23 to 24, 1923, which prevailed the entire length of the

Atlantic coast, this condition was well illustrated. For two days the northeast wind poured in below, while the vapor-impregnated southeast wind flowed over it, and a great rainfall resulted, in southern New England varying from four to five inches. But on the second day the warm current began to dominate on the middle and north Atlantic coast and finally reached the ground, displacing the cold air and locally sending the mercury up 10 degrees F. in a few minutes. This warm wind contained about three times as much water vapor as did the cold wind the day before. There were a few clearing showers as a cool, dry, southwest wind nosed under the muggy, southeast wind.

Intensity of Rainfall. The intensity of rainfall is dependent upon the rapidity of condensation and the speed at which a raining cloud passes over a place. Condensation is usually so slow that only light rain occurs. More than half the rainfalls do not exceed five-hundredths of an inch, and half an inch is considered heavy. But falls of one inch are common, and occasionally there is a rainfall of two inches or more in a day. The extreme is the western cloudburst, which is the result of the maximum of convection, a phenomenon typical of the Great Plains and the dry Southwest.

The uprushing air currents uphold the rapidly forming raindrops, until the accumulation of

water is extraordinarily great. A sudden collapse of the air columns permits the watery mass to descend, almost like a torrent. In mountain country where the entire fall tumbles suddenly upon a small watershed, the consequences to life and property are sometimes disastrous.

The severe thunderstorm provides what seems a small deluge, for here, too, the ascending air currents prevent the drops from falling except in localized areas, into which they may be poured from neighboring regions of ascent, and we have storms which partake of the characteristics of the cloudburst. If such a rainstorm becomes stalled, the downpour, continuing for an hour or more, makes several inches of rainfall and produces severe floods. The most intense rain that has fallen into a recording gage occurred at Porto Bello, Panama, in November, 1911, when the record showed a fall of 2.47 inches in three minutes.

Torrential Rains on the Front of a Mountain of Cold Air. The excessive rains which occurred in parts of the South and occasionally in other parts of the eastern United States during May and early June, 1923, were in many respects like the heavy rainfall characteristic of the windward face of a steep mountain. Unlike the mountain of solid rock, however, the obstructing mountain of cold

air is mobile, and often rushes forward under, or even falls onto, the warm wind. Instead of concentrating the heavy rainfall along a relatively narrow belt it spreads it over a considerable strip of country. Fortunate it is that such is the case, for instead of general rainfalls of two or three inches, or even ten or more inches in a day, as reported locally in the South, the falls at certain places might reach 20 or even 30 inches in a day, approaching some of the extreme amounts observed in India where the southwest monsoon strikes the Khasi Hills. At Cherrapunji, at an elevation of about 4000 feet, a rainfall of 40.8 inches was measured on June 14, 1876.

Once the warm, moist wind has risen over the mountain front, whether it be a front of rock or of cold air, the cooling has so reduced its moisture content that little more rainfall can occur. Anyway, beyond the mountain front the air tends to descend and be warmed by compression, thus dissipating the clouds. Hence the interior is rainless. In our West the driest deserts are behind the wettest mountains, so in the East dry weather is likely to occur in the Northeast while the South is being deluged.

Protracted Rainy Spells. Occasionally, a large region, such as the middle plains and parts of the South during the summer of 1923, is afflicted with

a period of protracted rain, when it seems to humanity as if the clouds would never stop forming, and the sun would never shine again for whole days at a time. This condition is usually caused by the presence of a great deal of moisture in the atmosphere covering a great area of country. A "cyclone" or "low" may become stalled, and remain nearly stationary, instead of pursuing a customary course across the continent. Much of the water vapor in the highly humid air condenses into clouds and rain. There may be a partial clearing permitting the sun's heat to cause further convection and to pump more moisture-laden air aloft, thereby producing more rainclouds, and this process may be repeated over and over again. Perhaps the moisture is replenished by the arrival of damp winds blowing from the Gulf Stream or Gulf of Mexico, further protracting the wet weather. Finally the excessive moisture is carried off in the rivers or is blown away by dry westerly or northerly winds, and the sun again shines.

Another cause of long-continued wet weather is a succession of energetic "lows," following close one upon another, each with its excessive rains, sometimes producing dangerous floods. It was such a condition that caused the destructive floods in northern Ohio in 1913, when the rivers rose 10 to 16 feet higher than had ever before been re-

corded, and caused loss of life and vast destruction of property.

Weight of Rainfall. One does not usually associate rain with great weight. Even when the clouds let loose a torrential downpour the mind reckons it in ounces rather than in tons. Yet one inch of rainfall deposits 113 tons of water on each acre of ground surface. The 7.24 inches which fell at Richmond, Va., the night of July 30-31, 1923, was 818 tons to the acre, an immense weight.

To take an extreme case, so far as known rainfalls go, that of Cherrapunji in India, on the watershed of the Ganges, nearly 30,000 tons to the acre has fallen in but one month, August. The average annual rainfall of 426 inches there comes to nearly 50,000 tons to the acre.

Reckoning rainfall by weight gives an impressive idea of the power of the sun's heat, through evaporation and the action of plants in drawing water from the soil and discharging it into the atmosphere. An inch of rain does not last long when the sun is bright and plant life is functioning. The 113 tons per acre soon disappears. The great weight is quickly returned to the air.

America is Rainier Than Europe. The densely inhabited parts of North America receive much more precipitation than those of Europe. Yet we hardly think we have more than we need nor do

FIG. 15. STRATO-CUMULUS CLOUDS. Such clouds are formed when upward forced currents of air in which condensation is occurring flatten against a lid or ceiling of warmer, lighter air, into which the rising air cannot be driven. (Photo by an officer in U. S. Air Service, Park Field, Tenn.) *See* pp. 35 and 36.

FIG. 16. CUMULUS CLOUDS. These clouds mark the tops of rising, upward forced currents or masses of relatively warm, moist air. When the cooling by expansion has reached the dewpoint the clouds form, with nearly level bases. Turbulence and evaporation make the edges ragged and finally cause the whole cloud to disappear. These clouds are generally thought of as fair weather clouds, though when they become well developed they may be the first step toward the formation of a cumulo-nimbus cloud, harboring a thunderstorm. (Photo by M. W. Lyons, Topeka, Kans.) *See* pp. 38-44.

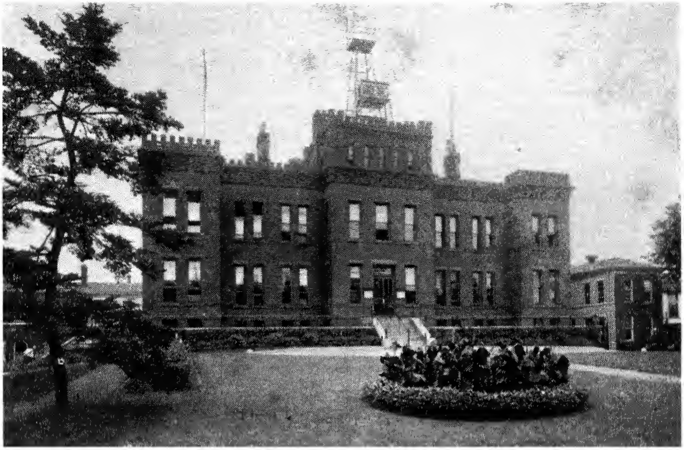


FIG. 17. CENTRAL OFFICE, U. S. WEATHER BUREAU, WASHINGTON, D. C. On the highest tower are wind vane, pressure-tube anemometer (for indicating the velocity even of individual gusts), and two anemometers of the revolving type. Below the high platform are two thermometer shelters containing a number of different sorts of thermometers, including a recording one, and a hygrograph (see fig. 6). In the building are located the offices of the Chief, the Editor, the River and Flood Division, the Forecast Division, Library, Aerological Division and others. The Instrument Division is in another building at the extreme left, while the Climatological, Marine, Printing, and Supplies divisions are beside where the photographer stood. This central office is the heart of the greatest weather service in the world, a service extending from the north coast of South America to Maine, from Maine to Hawaii, and from Hawaii to Point Barrow, the northernmost point of Alaska. It is probably safe to say that the people in this wide territory get more service per dollar spent by the Government than from any other Government agency. The whole cost per year is but two million dollars, or less than two cents per capita. *See* pp. 54 and 55.

western Europeans generally find that they have too little. The western European rainfall generally goes farther inch for inch than does that of eastern North America; for western Europe, generally, has its rains in smaller and more frequent falls and receives appreciably less sunshine than middle eastern North America. Less of Europe's rainfall runs off quickly in streams and less is lost by evaporation soon after it falls. The same advantage is held by places in western North America where rains and cloudy days are more frequent than in the east.

In comparing average annual precipitation totals, however, it is surprising to see how small is the depth of rainfall in European cities with which we commonly associate much raininess. It takes much drizzling rain to make an inch. Brest, in Brittany, so well known to American soldiers, has an average of only 32 inches of rain a year, which is less than that of Chicago with 33, St. Louis with 37, and Kansas City with 37. London, with 25 inches, is drier than Minneapolis, which averages 29. Paris has but 21 inches, which is less than that of San Francisco, 22 inches, while Berlin, with 23 inches is about the same. Athens, with 15 inches is even drier than Los Angeles and Salt Lake City with 16. Such rainfalls as 41, 45, 55, and 61 inches, the averages for Boston, New York, Wash-

ington, and Atlanta, are not found in large European cities. Only on the western slopes of bold coasts or mountain ranges as at Bergen, Norway (73 inches) and Lucerne (46 inches) are there corresponding rainfalls.

Spring Showers are Different. Spring showers are characteristic of the season. They have an individuality of their own. They come at a time when the ground is still damp from the melting snows and early spring rains, and when the atmosphere at moderate heights is still cold after the winter temperatures. The warm sun of the lengthening days heats up the earth's surface, and the lower air levels become warm and moist. The result is a sharp temperature contrast between the lower air and the atmosphere not very high above it.

The ground air expands, convection starts, and the vertical currents begin to flow, the hot, light air being forced up by the adjacent, cool, heavy air. The rising air expands and cools quickly, and clouds form at a low level, much lower than under similar conditions in summer.

After a while showers begin to fall. Sometimes thunderstorms are formed. A peculiarity of the spring shower is its short duration. Very often the day has alternate spells of showers and sunshine, as the clouds drop their larger particles in

rain, only to be replaced by other clouds as the pumping caused by the sun's heat sets the vertical currents in motion again.

The Rainbow. Every one knows the beautiful rainbow which always appears on a cloud of raindrops opposite the sun. Usually it marks the rear of a shower and a return to fair skies. It consists of seven concentric arcs which present successively the colors of the solar spectrum. Sometimes there is but a single bow, but usually there are two. The smaller is known as the primary bow, the larger, which is fainter, the secondary. On very rare occasions a third may be seen, not opposite the sun, but between it and the observer.

The colors of the primary and the secondary bows appear in reverse order. In the primary, the outer or highest band is red, the interior band violet or blue. In the secondary bow, the interior band is red, the outer band violet. Rainbows vary very much in appearance. Sometimes their bands are broader than at others. On occasion all seven bands may be counted, though more often not.

Rather narrow bands of color, essentially red, or red and green, often appear, parallel to both the primary and secondary bows, never between them, but along the inner side of the primary and the outer side of the secondary. They are known as supernumerary bows. These also vary greatly

in purity and color, the number visible, and the width, not only between individual bows, but also between the several sections of the same bow.

The colors are due to the unequal refraction of the components of sunlight, while the appearance of these colors in bows concentric to a point opposite the sun is because of one or more reflections of the light from the inner surface of the transparent drops. The overlapping of reflections gives rise to the supernumerary bows, in which the distribution of color provides an index to the sizes of the raindrops involved.

Rainbow, Cone of Colors. The usual conception of a rainbow is that it exists as if painted on a flat surface. Such is not the case, however, though it may appear that way to the eye. Looking at the rainbow the gaze is centered on the open end of a cone, the walls of which extend as far back as the farthest raindrop which is acting to separate the white light of the sun into its prismatic colors and turn them back in the direction of the observer. Physically, the phenomenon could be roughly reproduced by taking seven cones of glass—violet, indigo, blue, green, yellow, orange, and red—and telescoping them. Viewed at the open end the nested cone would be as the cone of the rainbow.

The intensity of the colors depends upon the

size of the raindrops, the larger the drops the more brilliant the coloring. The same phenomenon is witnessed in the dewdrop and in spray from fountains or waterfalls.

Height of the Rainbow. Were one high enough above the earth, the rainbow would appear not as a bow but as a complete circle. Not more than one-half of the arc is ever visible from the earth's surface, excepting from very high mountains. The reason is that the center of the rainbow circle is always as far below the horizon as the sun is above the horizon. Therefore as sunset approaches near, or soon after sunrise, the arch is nobly high and impressive, while as the morning wanes or in the middle of the afternoon only a small section of the arc is visible.

It is occasionally asked why the rainbow is not seen in the middle of the day. The answer is that when the sun is high in the heavens the entire circle of the rainbow is below the horizon, excepting from a great elevation, and therefore is cut off from sight.

Practically complete rainbows may be seen in the spray of waterfalls at any time of day, and even on dew lighted by moonlight or lamplight at night or by sunlight at dawn.

SECTION VII

MAY WEATHER

Lake Fogs Come in Spring. Fog is nothing more than a cloud formed at the earth's surface, touching the sea or ground. Seldom is it more than 200 feet in thickness. Like the cloud it results from the temperature of the air falling below the dew-point, which is the temperature at which the air is fully saturated and below which some of the moisture must separate out. The moisture condenses on the particles of dust which are always present in the atmosphere.

The usual fogs of the Great Lakes in spring are caused when warm, humid air floats over the cool surface, and loses heat to the water and further lowers its temperature by mixing with the colder air which it replaces. The most striking example, of course, is where the warm airs from over the Gulf Stream drift across the Labrador Current.

But the Great Lakes can do nearly as well. A balmy breeze from the south becomes chilled to a moderate height in passing over the icy water. This makes a fog in which vessels must grope their way, though an observer on a Michigan sand dune

could direct their movements, so sharp may the fog top be, no higher than the tops of the funnels.

Beware Late Spring Frosts. Late spring frosts are not uncommon in the northern United States, and sometimes cause heavy loss to market gardeners and orchardists, as well as doing damage to the flower gardens. Although the nights of spring are shorter than those of autumn, and therefore present less opportunity for cooling to the frost point before morning, the ground and the air aloft are both colder in spring, and the air is drier than in autumn. The more rapid cooling which occurs in consequence compensates for the shortness of time.

While it is the low temperature that kills, frost is what we see. It differs little from frozen dew. When the air temperature falls below the dew-point the temperature of the ground and vegetation is low enough to cause the formation of tiny ice crystals instead of water particles. It is the bright afternoon, followed by the still night with a clear sky, that offers the threat. Then is the time to cover vegetation with a nonmetallic something, if only paper, not to keep the frost out, as the saying is, but to keep the heat in by checking radiation from the ground and leaves. In the same way a smoke screen serves as protection against frost, taking the place of the cloud in

returning radiation; and this form of protection has come to be used widely in orchards when fruit buds are in danger. But orchard heating rather than orchard smoking is usually preferred, though the smoke and the heat operate to the same end.

May Cold Spells. In temperate America May rarely fails to have its spell of cold weather. The same condition exists in Central Europe, where the cold period is known as Kälterüchfälle, the return or "backslide" of cold. In the United States the Mississippi Valley averages colder in the winter than the Atlantic states, but in the spring the center of the continent heats up more quickly, tending to the establishment there of a pressure lower than that over the regions of Hudson Bay and eastern Canada, the Labrador Current and the Grand Banks, which are still icily cold from their snowfields and vast expanses of ice.

Hence once in a while this cold air flows southwestward, down into the United States, extending through New England and the middle Atlantic states, and the great central basin, including the Great Lakes and the region for several hundred miles south of them. Near the seacoast or the Lakes the mercury tumbles sharply and usually suddenly. Chicago's records give instances of a quick shifting of the wind from the southwest to

the north, the cold blast sweeping down over Lake Michigan, causing in a few minutes a fall of the mercury from 75° or 80° F. into the fifties. Along the New England coast these sudden falls with a northeast wind in spring and summer are known as "sea-turns."

Winds Aloft. Air currents in the free atmosphere flow under the influence of gravity just as water flows down hill; but the rotation of the earth so affects the moving air that, instead of flowing down the hill, it flows around it, or at right angles to the slope. Meteorologists call the imaginary hill down which the air tries to flow, a "pressure slope" or "gradient."

These pressure slopes in the free air are often greatly influenced by the temperature of the lower levels of the atmosphere. For example, on a winter's day, it may be excessively cold at Duluth, and balmy at New Orleans and Jacksonville. Under such conditions, the expanded warm air of the south and the contracted cold air of the north create in the upper air a pressure slope from south to north—and often a very steep one—so that in the free air the winds blow rapidly from the west over the region between these cities. On the other hand, on a warm day in summer, there may be very little difference in temperature throughout a wide region of the country,

and then the winds aloft are light and variable in direction.

A recent development in aeronautical meteorology has produced pressure maps of the free air which enable one to know, upon the basis of surface weather conditions alone, how the winds are blowing aloft, even when the sky is covered with clouds. These new charts were first used at the 1923 balloon race from Indianapolis, and they enabled the aeronauts to form better ideas as to the flying courses they wished to follow.

Balloon Racing and the Weather. Summer is not the best season for balloon racing, according to the late Dr. C. LeRoy Meisinger, aeronautical meteorologist of the U. S. Weather Bureau. The spring is the best time, for then there is a greater likelihood of good weather combined with a variety of wind conditions in the free air.

The free balloon, having no motive power for driving it horizontally, is carried along by the wind. It can be controlled by the pilot only in altitude. When he throws ballast overboard the balloon rises; when he allows gas to escape from a valve at the top of the bag, the balloon descends. The problem of the racing balloonist, so far as weather is concerned, is to plan a flying program that will enable him to take maximum advantage of favorable winds aloft. If, at various levels in

the atmosphere, there are air currents moving in different directions and with different speeds, the pilot is called upon to exercise his skill in the selection of an altitude where winds are most favorable. To illustrate the point, in the National Elimination Race from Milwaukee in 1922, the winner landed in Quebec, after only 17 hours in the air, while the winners of second and third places landed in Missouri after about 40 hours in the air.

In the race from Indianapolis, July 4, 1923, the balloonists encountered very light winds, and in several cases, severe thunderstorms, which are a serious menace to lighter-than-air-craft. Stagnant air conditions, with which thunderstorms are frequently associated in summer, prevent balloons from making great distances, and since these light winds may prevail to great elevations they limit the opportunity for the use of skill and judgment on the part of the pilot. Moreover, bodies of water, such as the Great Lakes, are not so hazardous when balloons are flying in moderate or high winds, since the time spent over water is thus lessened, as at times of light winds and thunderstorms.

Dry Northeasters. It is peculiar to have an ocean wind drier than a land wind, yet when the ocean is as cold as the western North Atlantic was

the summer of 1923, such has generally been the case. Consequently as ocean winds have blown for much of the time there has been generally dry weather. When the weather changes from warm sunshine and a west wind to cool, cloudy, perhaps foggy conditions, with a northeast wind, we say that chilly, damp weather has arrived. Yet if the weight of water contained in a cubic foot of the hot air were compared with that in the same quantity of the cool air we would find the moisture in the warm air perhaps twice as great as that in the cool air. The reason the cool air feels damp to us is that very little additional moisture is required for "saturation."

As this cool air goes inland from the ocean it passes over warm ground and becomes heated. The fog dissipates and the clouds evaporate, and the air becomes dry. The air has nearly as much water in it as before it came inland. Perhaps it has even more by virtue of water added by evaporation from trees and grass. Yet it is now the dry northeast wind, because at its higher temperature much more moisture would be required before "saturation" would occur. At some distance inland the air temperature of the northeast wind may rise nearly to the point of the previous west wind, when it will be very much drier than the west wind.

Summer, 1921, Affected Summer, 1923. The unusual weather which prevailed in eastern Canada and the northeastern United States the summer of 1923 seems to have been due in part not to recent weather happenings, but to conditions which had their origin two years ago, according to a British scientist who explains it this way: The warm summer of 1921 was marked by open stormy conditions in the Arctic Ocean, which set free great quantities of polar ice. This ice drifted with the Greenland Current, reached the neighborhood of Iceland in the spring of 1922, and in the succeeding months lowered the ocean temperature in that region. The result of this cooling, when communicated to the air, was to raise the atmospheric pressure in the northern ocean, which had the effect of driving southward the track of the "lows" as they passed eastward. This had a marked influence on the British Isles in the summer of 1922.

In the meanwhile the bulk of the ice continued to drift southward until, with the close of 1922, after rounding the tip of southern Greenland, it had got into the Labrador Current, which finally carried it into the North Atlantic off Newfoundland. Its influence was to push the Gulf Stream south of its usual position as it swung to the eastward across the ice-invested region.

The lowering of the temperature of the ocean

and the air above it, involving a great area, caused an increase in pressure, which, as it affected Canada and the eastern United States, resulted in northerly and easterly winds, as the air flowed obliquely from a region of high to a region of low pressure. This is held to account in large measure for the cool clear weather of May, 1923, especially in eastern Canada and northeastern United States, and perhaps for the cool weather, interspersed with very hot spells accompanied by northwest instead of the usual southwest winds that characterized June and July.

Cool Waves Made Drought. The very unusual persistence of dry weather during the summer and early autumn of 1923, broken only by short rainy periods in much of the northeastern United States and eastern Canada, is ascribable to the prevalence of dry air pushed out in very large volumes from stagnant areas of dry, cool air and high pressure to the north and northeast, the cause of which has not yet been fully determined. When the winds blew from the south or west they seldom prevailed long enough to bring enough moisture to favor the usual summer showers before the wind would shift again to a polar direction. Abundantly moist air having been absent there were very few of the local, or heat, thunderstorms, with their bountiful showers.

There was a limit, however, to the extent of the dry blanket of air, and beyond this heavy rains occurred during several periods from the Great Plains to the south Atlantic coast. In fact, the dry air outflowing from the northern and northeastern regions so nosed under or fell over the warmer and moister air in these sections that the rains were much greater there than if the warm moist air had not been so disturbed. The dry air stopped, elevated, and dried the moist air before it had an opportunity to travel more than a small portion of its usual summer journey northwards and northeastwards. Moisture usually distributed moderately and widely over the eastern North America was thus dropped in the South.

Drought and Nature's Water Supply. In a period of drought the earth may become dry to such a depth that only copious, long continued rains can drench the soil down through the arid stratum, which lies between the surface layer and the water-retaining floor below. Occasional showers, even though they give a heavy rainfall, cannot do it. In ordinary seasons this subterranean reservoir in a gravel stratum lies below dampened soil. The surface layer may become dry, but not so deep that the water of ordinary rainstorms does not penetrate through to the existing moisture, and

seepage downward is renewed and quickened. Therefore, the wells and such springs as are fed from the upper levels of the underground storage remain full.

In a drought, however, the subterranean reservoir, no longer replenished from the surface, gets lower and lower, and wells and springs which depend upon it give out in turn, according to their depths. They do not benefit from rains until the intermediate dry stratum has been penetrated and the seepage stream again is flowing. Most of the cold "boiling" springs, however, continue to flow, with practically unabated vigor, even in a severe drought, for they are fed from water stored so deep in the ground that it would be last to give out.

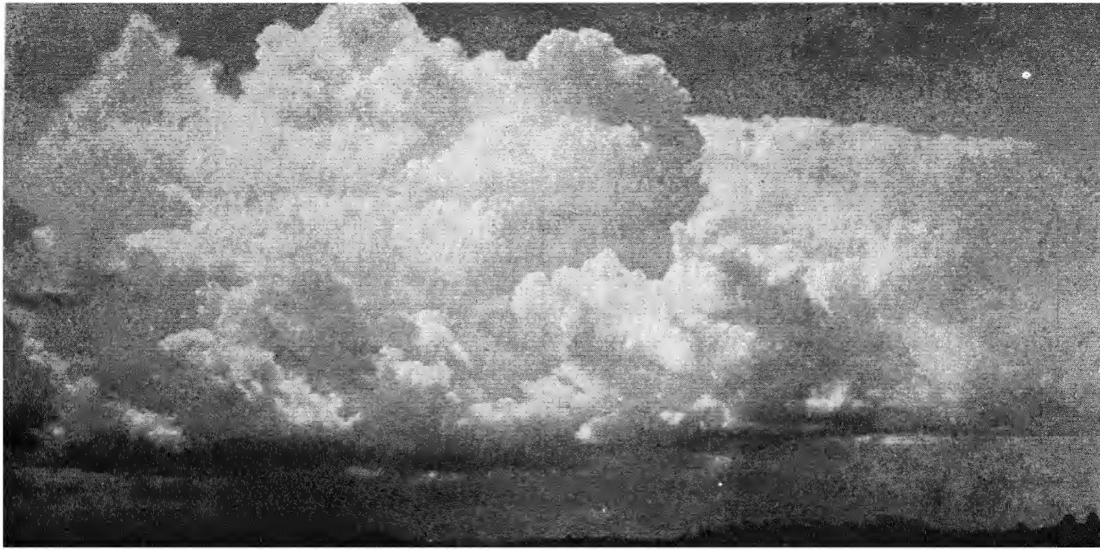


FIG. 18. A SPRING SHOWER. Note the massive thunderheads marking rapidly rising, relatively warm, moist air. On the left is a head in hazy disintegration—probably mostly snow. On the right is the flat top of the main portion of the shower cloud, or cumulo-nimbus. A cold wind at a moderate height blowing over well-sunned ground often results in showers of the type shown in this picture. Abundant hail, and heavy lightning and thunder are at times accompaniments of such a condition. (Photo by A. J. Weed, Mt. Weather, Va.) *See* pp. 68 and 69.

FIG. 19. ORCHARD HEATING WITH TALL-STACK OIL BURNERS. The lower parts of the stacks become red hot and radiate considerable heat. Owing to the fact that the lower, dangerously cold air is not usually very thick vertically, there is but a small amount of air to be heated to remove danger on most occasions. The warmer air above the cold surface layer forms a lid or ceiling which prevents the escape of the air artificially heated below.

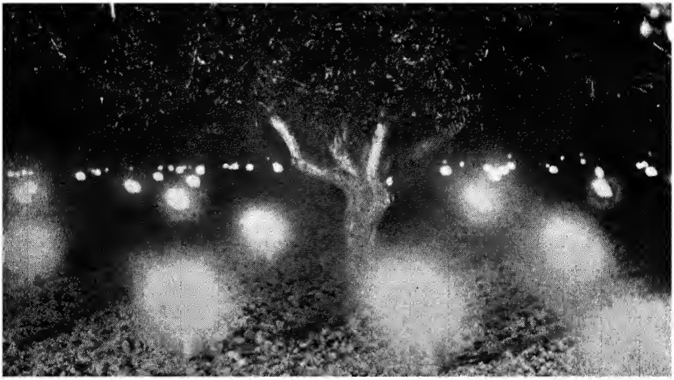


FIG. 20. SMALL OIL BURNERS. Numerous small oil burners have proved to be effective in protecting orchards against cold in quiet weather. Orchard heating is carried on mostly in the West, where dangerously cold weather is usually quiet. Orchard heating is not practicable where winds accompany the coldest weather at times when fruit may be endangered. *See* pp. 73 and 74.

PART II: SUMMER

SECTION VIII

SOME WEATHER PROVERBS

Truthful Weather Doggerel. Of the hundreds of weather proverbs, some of which date back to at least 4000 B.C., for they were inscribed on the clay tablets of Babylonia, some are based on accepted scientific fact. A group of these was brought together in verse, supposedly by Dr. Jenner, discoverer of vaccination. Dependable couplets follow:

> Last night the Sun went pale to bed,
> The Moon in halos hid her head,
> The boding shepherd heaves a sigh,
> For see! a rainbow spans the sky;
> Hark how the chairs and tables crack!
> Old Betty's joints are on the rack;
> Her corns with shooting pains torment her,
> And to her bed untimely send her;
> Loud quack the ducks, the peacocks cry,
> The distant hills are looking nigh;
> How restless are the snorting swine!
> The busy flies disturb the kine,

Low o'er the grass the swallow wings;
The cricket, too, how sharp he sings!
In fiery red the sun doth rise,
Then wades through clouds to mount the skies.
'Twill surely rain,—I see with sorrow,
Our jaunt must be put off to-morrow.

"Wet" and "Dry" Moon Fallacy. One of the hardest dying of the old false weather proverbs is that of the "wet" and "dry" moons. According to the fable, if the horns of the new moon tip downward, it is a "wet" moon, because it will not "hold water," and the month will be one of foul weather. But if the horns point upward it is a "dry" moon, because it will "hold water," and the month will be fair. This is the sheerest nonsense. Whether the horns tip up or tip down is because of astronomical reasons, and has nothing whatever to do with weather. Yet many people believe religiously in the adage. What difference could it make with the earth's weather whether the sun appears to shine a little more on the upper part than on the lower part of the moon?

The false proverb evidently arose from the fact that some months are unusually wet and others are unusually dry, while sometimes the new moon does "hold water" and sometimes does not. The coincidence of "wet" moon and a wet month or a "dry" moon and a dry month is remembered;

failures of the proverb are forgotten. If believers in the adage would take the opportunity to scan the weather records in their relation to "wet" and "dry" moons their belief would quickly waver.

Weather Uninfluenced by Moon.

The moon and the weather
May change together,
But a change in the moon,
Does not change the weather.

The doggerel is absolutely true. One of the commonest of all mistaken weather beliefs is that a change in the moon will bring a change in the weather. Let there be a drought and wiseacres assert, "When the moon changes it will rain." Let there be a protracted rainy spell and one hears told with complete confidence that the moon will change on such and such a day, and with it will come clearing skies and fine weather.

The absurdity of the belief is easily demonstrated scientifically. The moon's influence on the larger earth and its atmosphere is very slight indeed. Beyond its pulling power, which is the chief cause of the tides, and its pleasant illumination at night, it has practically no effect at all. Furthermore, an examination of the weather records demonstrates that changes in weather occur

just as many times in between changes in the moon as during them, and that "highs" and "lows" come and go regardless of the satellite.

Old Moon in New Moon's Arms. While the ancient weather saw that "when the new moon holds the old moon in its arms" foul weather is at hand, may not be attacked as an astronomical absurdity as in the case of the "wet" and "dry" moon, still it is difficult to ascribe to the phenomenon any degree of reliability. In fact, the proverb is also used to portend fair weather. The saying applies when the full orb of the new moon is visible, though but dimly, excepting where the rim is brightly illuminated as a crescent. Ordinarily only the crescent is visible.

When the old moon is thus seen, the atmosphere is very clear, and probably this is the chief reason. Clarity of vision results from the purity of the air in respect to water vapor and dust. Or, as sometimes happens, the usual distortions and wrinkles caused by irregularities of temperature have been wiped out by a warm wind and for that reason the air has been made clearer than usual.

One theory of the "old moon in the young moon's arms" is that it is receiving exceptional illumination from reflected light from the earth. Clouds reflect as high as 78 per cent of sunlight, while water reflects less than 50 per cent, and the

ground still less, ranging down to nearly no reflection from black soil. If the new moon is receiving this reflected light in exceptional amount, it must come from the sunlit portion of the earth, that is, from the west, which would mean that great areas to the west of us are overcast with clouds and stormy weather is present in the direction from which storms approach. Hence, if this reflected light theory were correct, the old moon cuddled in the arms of the new moon would naturally be a harbinger of bad weather. However, it has been reckoned scientifically that such cloud-reflected light, even if the sunlit hemisphere of the earth were clouded one-tenth more than usual, would increase the moon's illumination hardly more than 2 per cent, which would not account for the greater distinctness with which we see it. The fact of a very clear atmosphere would better explain the phenomenon, and this clarity comes more often from the clear air, which indicates fair weather, rather than foul, for several hours, if not for a day or two. Under certain conditions, however, when the clearness is owing to the descent of air in front of a rapidly moving, intense storm the old moon in the new moon's arms is a portent of stormy weather.

When Scalps Are Wet. The American Indians had a gruesome proverb: "When the locks turn

damp in the scalp house, surely it will rain." It was a well-founded proverb, for the humid condition causing damp locks, also favored rain. It is an interesting fact that the most serviceable instrument used in meteorological science for the measuring of humidity, the hygrometer, makes use of the human hair as the fundamental factor in its mechanism, so susceptible is it to the presence or absence of moisture.

Before being used in a hygrometer children's hair is treated so as to rid it of its natural oil. Then a bundle is made up and fastened at one or both ends, and held moderately tight by a weight or spring to which is attached an indicator. When the air becomes moist the hair elongates; when the air becomes dry the hair shortens. The changes in length correspond almost exactly to the percentage changes in relative humidity without respect to the temperature. So, too, does moist air twist tighter the natural curl, while artificially curled hair straightens out.

Sun Does Not Draw Water. A familiar phenomenon of sunrise and sunset is that of "the sun drawing water," which is popularly supposed to forebode a storm. Lines of alternate light and shade seem to radiate from the sun, which itself is concealed by heavy banks of clouds. The effect is one of much beauty, particularly where there is

a tinge of color. Meteorologists call the phenomenon crepuscular rays.

The cause is the presence of dense, bunchy clouds through the interstices of which the light-beams pass, in clean-cut contrast to the shadows cast by the clouds. The rays, though practically parallel, appear to broaden as they approach nearer to the eye of the observer, like the rails on a straight track.

As the phenomenon would not be well defined were it not for the presence of dense clouds and haze resulting from a considerable amount of moisture in the atmosphere, there is some truth in the belief that "the sun drawing water" may be a portent of approaching wet weather.

Evening Red and Morning Gray. Beware of weather proverbs. Or, better still, pick the true ones and throw aside those which have not been proved. A good one which has survived the test of time, even from the days of Christ, is that

> Evening red and morning gray,
> Help the traveler on his way;
> Evening gray and morning red,
> Bring down rain upon his head.

Christ, asked for a sign from Heaven, said: "When it is evening, ye say, it will be fair weather: for the sky is red. And in the morning,

It will be foul weather to-day: for the sky is red and lowering.''

When the sun shines clear and reddens the western sky there are no clouds for a long distance to the west, and the normally dusty atmosphere is transmitting the red rays of sunlight in larger measure than the blue ones. Since the weather usually comes from the west this indicates fair, dry weather for some distance in that direction. If the following night is clear and the upper air dry the cooling by radiation will be so favored that it is likely to produce a fog as water condenses on the cold dust particles. This makes the ''morning gray.'' Thus, both ''evening red'' and ''morning gray'' indicate the same condition: clear dry weather, which ''helps the traveller on his way.''

On the other hand, when the western sky is banked with dense clouds, giving ''evening gray,'' and when on the following morning the rising sun shines red through fogless, dusty atmosphere, and perhaps lights up the under surface of the cloud sheet which has spread over the sky during the night, the dry weather is evidently to the east, and the wet weather with the thickening clouds is near at hand in the west, and will ''bring down rain upon his head.''

"Rainbow in the Morning."

Rainbow in the morning, sailors take warning,
Rainbow at night, sailor's delight.

This old jingle tells a weather truth. The sun shining from the east in the morning throws the rainbow on raining clouds in the west, which is the direction from which showers usually come. Therefore, it is highly probable that foul weather is immediately at hand, and sailors who see the morning rainbow know they are about to have rain.

But the significance goes farther. As is implied in the similar proverb, "Thunder in the morning, sailors take warning," morning showers or thunderstorms usually occur only with warm humid air flowing under cooler, drier air, through which nocturnal radiation has been sufficient to cool the top of the layer of humid air to a point where its increased weight causes it to descend, violently overturning the warm air below. Such showers and thunderstorms, marking as they do the presence of warm, humid air, may open a period of showery weather. The "rainbow at night," which we take to mean at about sunset, indicates clear skies to the west and shower clouds to the east, a condition usual just after

the passage of showers and at the onset of a period of fair weather. But even if there is no change in general conditions the late afternoon shower responsible for the rainbow indicates that it took the maximum convection of the day to give the storm, hence that the atmosphere is rather dry and general rains improbable.

St. Swithin's Day. According to the ancient English legend if rain falls during St. Swithin's Day, July 15, it will rain for 40 days. Of course, it sometimes rains on St. Swithin's day, but the 40 unbroken rainy days do not follow. The belief in the adage is fostered by the occasional period of daily showers coincident with a rainy July 15.

St. Swithin, an English ecclesiastic of the 9th century, became Bishop of Winchester, and upon his death was buried at his request just outside the church where water might drop from the eaves on his grave and passersby might tread on it. A century later he was canonized and it was determined to remove the body from the grave to the church. According to the legend the good saint's protest was a rain which delayed the transfer by enduring for 40 days.

Why Stars Twinkle. The twinkling of stars, which technically is known as scintillation, is not due, as popularly supposed, to ebullitions of light at its source in a fiery sun, but to conditions in the

earth's atmosphere through which the light rays pass. The atmosphere is always far from homogeneous, consisting of pockets and layers of air of very different temperature and moisture content, and thus of different densities. These layers and pockets are moved about and mixed by wind. As a result the condition of the air through which rays of starlight come to the eye is different each succeeding moment, and the amount of refraction, which is the bending of the light rays, is constantly changing. This is the chief cause of the small changes in position which we see as twinkling. When a star is viewed through a telescope this change of position is sometimes so marked that the star fairly dances in the field of view, and astronomical observation is impossible.

Similar atmospheric conditions also cause two other components of twinkling, change in brightness and change in color, the latter due to optical interference, which may cause destruction of certain wave lengths or colors. Twinkling is much more violent near the horizon because the thickness of air through which the starlight comes is there much greater. The reason that planets do not twinkle, except sometimes when they are very near the horizon, is that they appear as discs and are not mere points of light like stars. Each point on the disc twinkles but the twinklings do not keep

step, so that the average condition of the whole disc is much more nearly constant.

Smoke Makes Copper Sun. In times of drought the forest or prairie fire has far-reaching effects upon the atmosphere, for the almost infinitesimally small particles which compose smoke often travel great distances. As they drift across the country a haze is created through which sun or moon shines purple or orange or red, usually like a disc of copper. The smoke particles scatter the shorter waves of sunlight, the violets and blues, and therefore accentuate the long wave colors, the yellow, the orange, and the red. This was the cause of the famous yellow day of New England, September 6, 1881, when that part of the world was bathed in a ghastly light, so dim as to make necessary the use of artificial illumination indoors.

On a smoky day, the sun appears orange or red by transmitted light, but in other directions the haze is blue by scattered light. A similar effect may be obtained by filling a bottle with soapy water, the soap particles acting much the same as the smoke in the atmosphere. Hold the bottle toward the sun and its contents show an orange tinge. But hold it in a direction more than 90 degrees from the sun and the water appears blue.

Heat and the Cricket's Beat. The cricket

chants, and the ant runs faster or slower as the mercury goes up or down. Dr. Harlow Shapley, director of the Harvard College Observatory, learned how to get air temperature to within one degree Fahrenheit by timing the speed of ants. The higher the temperature, the higher was the speed. Another observer worked out a schedule by which he claimed he could tell with some approach to accuracy the reading of the thermometer by counting the pulsation of the cricket chorus. On a very hot night the beat would ascend to nearly 125 a minute. A sudden change in weather, lowering the mercury, would bring with it a corresponding slackening of the chant. It has been counted as low as 60 to the minute, following the cooling effect of a thunderstorm, where a little while before, with the mercury hovering in the 80's, it was 120.

The cricket is also credited with singing much louder as a storm approaches, but this is ascribed not to the vocal power of the insect, but to the fact that sound comes more clearly to the ear because of locally homogeneous atmospheric conditions which usually immediately precede foul weather.

Dog Days. The Dog Days, associated with the greatest heat of the year, an atmosphere frequently muggy, thunderstorms, and vacations,

begin July 3 and end August 11. Recognition of this particular period of weather had its origin in remote antiquity. The name comes from Sirius, the Dog Star, most brilliant of the fixed stars. The Dog Days comprise the period of the rising of Sirius with the sun, from 20 days before their simultaneous rising to 20 days after, in other words:

> When Sirius rising with the sun
> Marks the dog days well begun.

Of course, the rising of the Dog Star does not in itself influence weather, though many people attribute to it this malign influence. But its rising with the sun about July 23, midway of the 40 day period, is an excellent marker for the interval of the year when disagreeable, hot weather conditions are most apt to prevail, particularly heat accompanied by dampness.

SECTION IX

SUMMER WEATHER

Forecasting in June. Summer is the calm time of year and the calm time in the life of the weather forecaster, yet it is not without its thrills. There are no general storms, gales, snowstorms, and cold waves to look out for; but there are hot spells and thunderstorms and after July along the eastern coasts the West Indian hurricanes must be watched. April showers have dried up; the cool fair weather of May has weakened under the attack of the sun. The sun, in fact, is boss. Seldom does a day begin so ill that the warmth of his beams is not sufficient to pierce the clouds and warm the earth. Nights may be cool, but the days are warm and there is more difference between the day and night temperatures than between those of succeeding days. "Fair and somewhat warmer" is a good forecast.

But the weather does change. The sun has some competition. The Great Lakes are still almost icy cold. Ice floes and icebergs are still drifting down from Labrador and Greenland.

Warm air from the interior of the country rises and drifts away at the upper levels to settle perhaps over the cold water of the Lakes, Hudson Bay, and the Labrador Current. Still warmer air is drawn in from the Gulf of Mexico and the Gulf Stream. The east experiences a hot wave.

Then the cool air from the north and northeast creeps in under and over the warm, humid air; there are general thunderstorms and the hot wave is broken. It is the forecaster's job to tell when all this is going to happen, a matter of great interest to the farmer, the ice man, and the summer vacationist. So early summer is not such a serene and placid time for the weather man as one might expect.

The Summer Northeaster. The summer northeaster is a localized disturbance, differing in many respects from the fierce, northeast gale of winter, which sweeps up the length of the Atlantic coast, accompanied by heavy snow on the northern coast and rain and snow to the southward. The hot weather variety is very different indeed. The "highs" and "lows" of summer pass more deliberately, and their pressure contrasts are not so great.

Occasionally in summer a "low" gets stalled off the New England coast, most often off the shores of southern New England, coincident with the

FIG. 21. ONE DISTANT LIGHTNING FLASH AT NIGHT. The notch in the landscape where this streak appears to end was more than a mile away. On several occasions lightning was seen to strike in the same place. (C. F. Brooks, Wayzata, Minn.) *See* pp. 129-132.

FIG. 21. ONE DISTANT LIGHTNING FLASH AT NIGHT. The notch in the landscape where this streak appears to end was more than a mile away. On several occasions lightning was seen to strike in the same place. (C. F. Brooks, Wayzata, Minn.) *See* pp. 129-132.

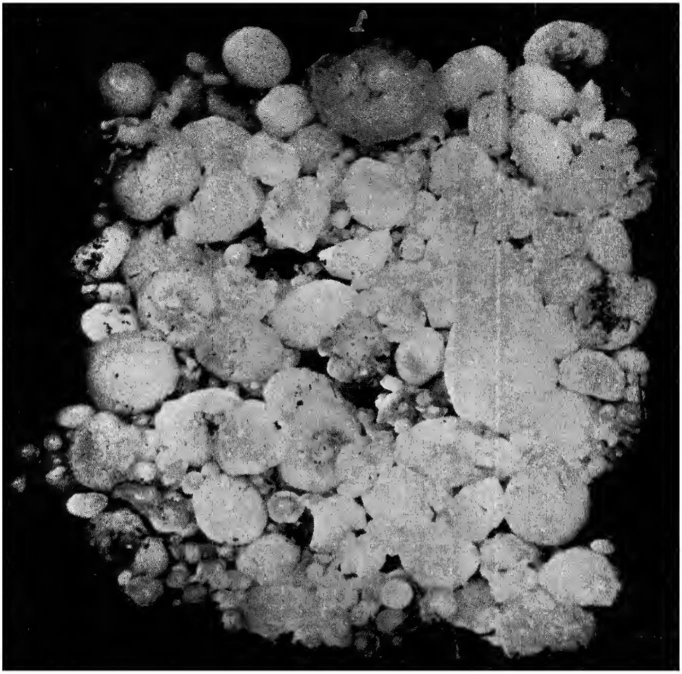


Fig. 22. Hailstones of Great Size. (U. S. Weather Bureau.) These fell at Concordia, Kansas, June 23, 1893. The largest (1) was 13½ inches in circumference. *See* pp. 136-137.

presence of an area of high pressure to the north and northeast, over the northeastern portion of the continent and the Labrador Current. The air, cold from contact with the ice fields, pours southwestward around the low. As a wedge it lifts the warmer air in its path and produces clouds, then rain. With an increased flow of the northeast wind the overriding southwesterly wind becomes stronger, and then for a day or more copious rain may fall from the expansionally cooling warm wind rising over the cool wedge at the surface, and overturning with cool air higher up.

While the summer northeaster has little of the violence of its winter counterpart, it is much longer protracted, sometimes lasting for three and even four days. So local is the type that, for instance, while the territory from eastern Massachusetts to New York City may be heavily overhung with raining clouds, the country to the northward is bathed in sunshine.

Summer Southeaster. Of the summer storms in the eastern United States, the southeaster is wettest and windiest, excepting, of course, the short-lived thunderstorm and the rare hurricane and tornado. It is not so enduring a disturbance as the warm weather northeaster, nor is it characterized by so low a temperature. But usually it

gives a heavy rainfall, and may be accompanied by a wind of gale-like proportions.

The southeaster forms in a "low" a short distance inland, when a pronounced "high" lies off over the Atlantic to the east. Warm, moist air from the Gulf Stream flowing slantwise from the "high" to the "low" strikes the barrier formed by a similar flow of the cool air from the east or northeast and rises up over it. In the process the warm air is cooled, mostly by expansion, slightly by mixture, and much of its moisture condenses as rainclouds.

Usually in a southeaster the pressure gradient is a steep one, which is to say that the difference in air pressure between the "high" and the "low" is large. Consequently, the flow of warm air is swift, condensation is very rapid, heavy clouds form quickly, and much rain falls, sometimes as much as 3 inches in 24 hours. Vacation sojourners detest the southeaster as a period of driving rain, which blots out the landscape, and, unless they are hardy souls who do not fear a wetting, keeps them cooped up within doors.

The Summer Solstice. Summer begins about June 21, so the astronomers say, that being the time that the sun reaches its farthest north and begins its six months' journey back towards the Tropic of Capicorn. After that date, or some-

times June 22nd, the intensity of the sun's rays, which has been increasing for six months, decreases week by week as they strike more and more slantingly on the ground.

Why then do the astronomers say that summer begins when the sun begins to slack up on his job? Meteorologists count summer as beginning June 1 because the ensuing three months are, taken together, the warmest of the year, but both they and the astronomers agree that as the nights begin to lengthen the heat begins to strengthen, to paraphrase a familiar saying.

Why July is Hottest. As the sun comes northward the heating of the earth lags behind the increased heat of the sun. On June 21st or 22nd when the sun turns south the temperature of the ground and of the atmosphere are still some weeks from their maxima. The surface of the ground has to be heated and often dried as well. The layers of earth directly below the surface quickly take up some of this heat. The air in contact with the ground heats from the ground, but no sooner does it get somewhat warm than cold air from above or from a cooler, perhaps grassy, place flows down or under and forces this warm air up. It takes some time by this process for the heated ground to warm an appreciable layer of the atmosphere.

So, even after the heat from the sun begins to diminish, it is still more potent in warming the air than radiation is in cooling it. As the air becomes warmer, however, the radiation loss becomes greater, while the heating by the sun becomes less, until at about a month after the highest sun the cooling becomes stronger than the heating, and the temperature starts down.

The same principles apply to the daily course of temperature, which shows a maximum two hours or more after noon. In an arid climate the delay is not so great as in a humid climate, for the dry, bare ground heats and cools more readily.

North Pole Sometimes Gets More Heat Than Equator. On the longest day in the year, the sun climbs highest in the sky at noon. At the North Pole the sun rides around the sky from midnight to midnight at 23½ degrees above the horizon and provides as much heat every hour there as it does at the noon hour on December 22 in the latitude of Portland, Me., Syracuse, N. Y., Grand Haven, and Milwaukee. The sun is higher in the sky on this day throughout the United States except for a narrow strip from northern Minnesota to Vancouver Island than it is on the equator, and it stays above the horizon hours longer. The sun may shine for 15 hours and 37 minutes at Minneapolis, for 15 hours and 13 minutes at Chicago,

for 14 hours and 31 minutes at Chattanooga, and for 14 hours and 5 minutes at New Orleans. On the equator it can shine but 12 hours and 7 minutes.

Even where the noonday sun is no higher along the northern border of the United States than it is at the equator, its rays are more intense, for our absorbing screen of water vapor is thinner than that of the equatorial regions. Is it surprising then that our heat sometimes surpasses that of the tropics and that sunstroke invades our latitudes?

Eastern Hot Spells From Northwest Winds. The extreme hot spells, which, interspersed in generally cool weather, characterized the first half of the summer of 1923 in the northeastern quarter of the United States and adjoining Ontario and Quebec, were remarkable in that they were caused by hot winds from the northwest instead of from the southwest, as is usual. Because of this wind direction the weather was hot and also dry, and so less muggy than in the ordinary hot spells of other summers.

The air flowed from one to two thousand miles over dry ground heated from early morning to late evening by the sun blazing through a nearly cloudless sky. Such large volumes of hot air were sometimes involved, starting from the Great

Plains, that even the Great Lakes, cold as they were, seemed to have little more than local influence on the temperature. The chilling which did occur may have condensed some of the water vapor and so dried, rather than moistened, the passing air.

The usual southwest wind of hot weather cannot prevail for long without importing so much moisture that clouds soon screen the earth, and local thunderstorms cool its surface. The air does not get so hot, but humidity makes the heat oppressive. We swelter rather than bake.

Eighteen-Hundred-and-Froze-to-Death. Early in 1923 when announcement was made of continued abnormal warmth in the Arctic Ocean and the arrival of unprecedented, vast masses of ice in the North Atlantic, the weather alarmist dwelt with relish on the possibility of a repetition of the famous summer of "eighteen-hundred-and-froze-to-death," meaning the year 1816, the summer of which was filled with strange, disastrous contrasts of weather, from 100 in the shade to snowstorms. Looking backward, the alarmist has the solace of knowing that the summer of 1923 in eastern North America had certain points in common with that of more than a century ago, when crops failed because of excessive cold weather which, however,

was punctuated with hot spells of terrific intensity.

In 1816, according to Perley's Historic Storms of New England, about May 23 three hot days occurred which gave Salem, Mass., the hottest weather in 10 years, 101° Fahr. On June 5 it was again hot in Salem, the mercury rising to 92. But the next morning it was 43°, and there were snow flurries in parts of Massachusetts. On the 7th snow covered the ground at Newton, Mass., and was a foot deep in Williamstown, Mass. Yet on June 22-24 came three days of 93°, 101°, and 100° in Salem. Then followed more cold weather.

The summer of 1923, likewise, had its cool weather and hot spells. There was even snow reported in July in the Berkshires and in the Canadian Northwest. The hot waves of June 4-6 and June 19-21 were much the same as those of 1816. The dryness of the air coming off the cold waters of the enlarged and well-iced Labrador current, the abnormally cold Great Lakes, and presumably of Hudson Bay as well, curtailed the cloudiness. As long as the winds blew from off the cold water the weather stayed cool in spite of the sunshine. But when the wind shifted to a westerly direction the temperature bounded up as the hot air was transported from the center of the continent, which

had been out of the reach of the coolness of the east winds, but had not escaped their dryness.

The Hot Wave. The hot wave results when an area of high pressure covers the southeastern states, while an area of low pressure advances from the west across the northern states. The heated air of the rear of the "high" pours northward, not directly toward the "low," but to the right of it, in summer giving the sun in a clear sky opportunity to send the mercury into the 90's in the afternoon and causing much suffering.

The summer hot wind is usually accompanied by increasingly humid air, as the heat evaporates local moisture, adding it to the greater and greater imported water vapor. Usually by the third or fourth afternoon, the moisture is sufficient to allow the formation of local thunderstorms. Before another day passes the hot spell is terminated by windshift line thunderstorms, sometimes of terrific violence, with torrential rains and occasional tornado-like windstorms, the immediate cause being the approach of the cool wind of the front of the succeeding "high," which, in contact with the hot, moist south wind, results in violent, vertical convection and abundant condensation.

Keep Cool. On a warm summer day our bodily heat production, particularly if we are active, may be far more than that required to maintain a nor-

mal temperature. But we do not have a fever, as we are constantly being cooled by radiation, conduction, and especially by evaporation of moisture from the skin and lungs. Evaporation takes place most rapidly when the air is dry and circulates freely.

The cooling power of air, then, depends upon three things: its temperature, its motion, or velocity, and the moisture in it. These are the factors which determine the sensible temperature, or how hot it feels. It will be readily seen that this is not the same as the actual air temperature. After an electric fan is turned on in a room it may feel much cooler, though the air temperature remains the same. Electric fans may more than double the cooling power of the air.

If the air is warm and "saturated," or nearly "saturated," with moisture and there is no breeze, we can evaporate but little perspiration and find a temperature of 75°, or with slightly lower relative humidity 80° or 85° F., quite oppressive. Such conditions are frequent in the Gulf States. In Calcutta, India, electric fans are employed outdoors to give relief to Europeans. On the other hand, on a dry day with a good breeze, one can remain relatively comfortable even though the thermometer registers 90° F.

The importance of cooling power in relation to

comfort is illustrated by experiments with air-tight cabinets, like a telephone booth. A man shut up in such a cabinet can remain comfortable if he is kept cool by an electric fan, even though the air becomes so depleted of oxygen that his cigarette will not burn. Turn off the fan and allow the man to become too warm and he will soon show symptoms of distress even though he is allowed to breathe fresh air through tubes connecting with the outside. Deaths attributed to suffocation are really more often due to heat prostration.

The Asphalt Mirage. The asphalt mirage is a phenomenon peculiar to the hard, smooth highway when the sun is beating down hotly upon it. Motorists may observe it as they ascend a gently graded hill and approach a level stretch. The road ahead seems as if covered with puddles of water. Sometimes it glistens as if the sun were reflected from a shallow flood. But there is no water. The roadbed is perfectly dry. The observer sees a mirage.

On a very clear day, when the sun's rays burn fiercely upon the asphalt or other hard road, its surface becomes greatly heated and a thin layer of very hot air forms upon it. The stratum above it is much cooler. The difference in density between the two layers is so great that the light rays are bent upward, the refraction acting in effect as

would a mirror. The motorist does not see the highway's surface but the sky as if reflected in that surface. Were such conditions perfect, clouds might be seen "reflected" as in a body of water, and the illusion thus still further increased.

Dust Devils. While the whirlwind in its extreme form, the terribly destructive tornado, is fortunately unfamiliar to most people, especially in the eastern states, every one, whether living in city or country, is familiar with dustwhirls or dustspouts, or dust devils as they are commonly called in the deserts of the Southwest where they are most common and form on a larger scale. In the country on a hot day a dustwhirl is sometimes seen running along a road, sending a column of dust up in the air, spinning like a top. In the cities they gather up scraps of paper and other light debris and scurry along the street or across the yards.

When the sun on a clear, still morning heats up the air close to the ground until it is much warmer than that a few hundred feet aloft, chimneys of updraught are formed which rotate at great speed. In the desert they sometimes carry dust several hundred feet in the air, and are seen moving slowly along the ground, conspicuous at a considerable distance.

The Apache Indians used to make use of dust-

spouts as signals in the desert, creating them by the artificial heat of the blazing spines of a column-like cactus which is common in the Southwest. Under right conditions enough heat was thus obtained to start the whirling updraught.

Cool Spots on Hot Night. In driving through the country on a still, clear, warm evening one occasionally passes into a zone of coolness. The effect upon the body may be one of real chilling, so sharp is the contrast on entering the colder, damper air. The mercury fall may be as much as 10 degrees in a few rods of highway.

Two influences cause this phenomenon. The less important is that the bottom of the hollow to which the condition is confined passes out of direct sunlight into the shadow earlier than the land about it, as does also the slope next the sun. The more important cause, however, is the drainage of cool air from the slopes into the hollow. The higher land gives forth its heat more quickly than the lower land, this cooling action being in evidence soonest on the slopes which entered the shadow early or were shaded by dense trees. The air in contact with the ground or in the woods becomes cool and therefore heavier than the warmer air below, and slides down hill into the lowlands, materially reducing their temperature. On still evenings the moisture from evaporation collects

over damp lowlands, and humidity becomes so high that a relatively slight decrease in temperature may bring the air below its dewpoint and form a fog.

The Mugginess of Lake Shores. The shores of small lakes, where in summer the water reaches temperatures of 75° to 80° F., are likely to be very muggy as compared with the surrounding country, when the weather is warm and the winds light. In hot spells the lake water and the air resting upon its surface are cooler than the surrounding atmosphere. This relatively thin layer of cool air, undisturbed by the warmer air above it, retains practically all of the moisture evaporated from the lake and thus becomes very humid. The layer spreads out to envelope the shores, and a condition of extreme mugginess is created. In cool weather this effect is not felt, for the surface layer, under these conditions warmer than the surrounding atmosphere, is rapidly replaced and dissipated by the cool air.

North, northeast, and east shores of small, and especially of shallow lakes, and even the beaches of sheltered ocean bays are most affected by the mugginess created in hot weather. An interesting example of the warming action of the sands of shallow bays is found on the inside shores of Cape Cod. The temperature of the incoming tide on a

hot, sunny day in midsummer at Provincetown rises to above 90° F., which is 15 degrees or more higher than the water at the surface of Massachusetts Bay a mile or two from the shore. Under these conditions the relative humidity near the shore has been observed to be 75 per cent, while at the top of the Pilgrim Monument, close by, but about 300 feet higher, it was 47 per cent.

Last Day of a Hot Spell. The last day of a hot spell is usually the hardest to endure, for in addition to the cumulative effects of hot weather the temperature and humidity are highest, and the wind is weakest. The atmospheric pressure is about at its lowest, which is the chief reason why the breeze which started the hot wave has died down. Much suffering results, for to any one in a perspiration a good wind of fifteen miles an hour is nearly twice as cooling as a light breeze of but four.

On such days cities like Boston, where the wind is off-shore, get much hotter than the interior. A place near sea-level is usually warmer than one at even a moderate elevation. Furthermore, the very presence of the cool ocean near by becomes a liability rather than an asset as the land wind weakens. The overflow of some of the expanded air from the heated land to the cool water increases the pressure just off-shore while it decreases it

just inland. The resulting tendency for a sea-breeze to set in just balances the pressure gradient causing the general breeze from the land, bringing about a dead calm when the sweltering heat is most intense. But by nightfall the sea-

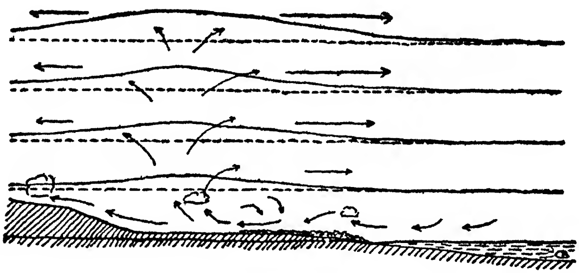


Fig. 23. Air Circulation in a Sea Breeze. The air over the land, being heated, expands and overflows to sea, raising the pressure over the water and lowering it over the land. A flow from sea to land takes place, in consequence, along the surface. Local irregularities in circulation are caused by rough topography. (Drawn by C. F. Brooks, and reproduced by courtesy of Bellows-Reeve Publishing Co., publishers of an encyclopedia of agriculture for young folks.)

breeze may conquer the waning land wind, and bring a welcome but dangerous chilling to the overheated people.

The Sea Breeze. Residents of the narrow strip lying within a few miles of the Atlantic Ocean or the Great Lakes regard the lake or sea breeze, or east wind, as it is often called in the North Atlantic cities, as one of their blessings. Each quiet,

hot summer day, as the heat grows intense, a cool wind springs up, coming from over the water and, when from the ocean, scented with the odor of the seashore. It is wonderfully refreshing, especially to residents of cities. The hotter the day the stronger is the sea breeze, for its cause is the contrast between land and water temperatures.

On such a day the hot sun heats the earth and this in turn heats the air. The heated air expands, and some of it spills over above the denser air over the water, lowering the pressure over the land and raising it over the water. In consequence of the difference in pressure so created, the flow of cool air from the sea starts in, first at surface level and gradually extending to greater heights as the heated air over the land continues to flow out to sea, aloft.

The influence of this phenomenon extends comparatively few miles inland, as a rule. As in quiet weather the intensity of the breeze depends upon the degree of contrast between land and ocean temperatures, quite naturally fresher breezes blow from the cold water off the New England coast, than from the warmed water off the shores of the Southern States.

Where Mercury Never Changes. Where there is a spring of pure cold water the flow of which never ceases and the temperature of which never

changes, it is an easy matter to find the average annual temperature of the surrounding country, for it is essentially the temperature of the spring. In the northern United States it will not be far from 50 degrees Fahrenheit. It comes from "the layer of unvariable temperature," which lies from 50 to several hundred feet down in the earth. The depth is too great to be influenced by atmospheric variations, and not great enough to feel the heat from within the earth. There are cellars so deep as to enter the layer, and there temperature remains constant the year through. And that temperature is proved to be the average of the open air above. The water which flows through the layer takes the temperature with it as it bubbles forth into the daylight. Springs from shallower sources vary in temperature, but their average temperature is that of the region. The rare exception is the spring of constant temperature from a level below that of unvariable temperature, in which case it is slightly warmer than the mean of the climate. But generally speaking, the real "bubbling" spring is a dependable climatic thermometer.

Summer Ice Caves. Towards the end of summer the last of the accumulations of ice in some caves, mines, and wells are melting. In a few the ice will not disappear before a new crop begins to

form. Caves, mines, or cracks in which ice is to be found in summer are those in which in winter either a very great depth of snow and ice collected, or cold air entered to such an extent that the walls were chilled and froze the inpouring water from the spring thaws. A reversal of the seasons seems to result: the succession of cold inpourings of air in winter though making very low temperatures, may not form icicles till spring when the water comes. Then the ice melts so slowly that it is present most of the summer, for the warm air cannot enter to displace the heavier cold air in the hole, and the conduction of heat through the rocks is so slow that it takes half a year for the summer heat to be felt at a depth of 30 to 50 feet. By the end of summer, however, the last of the ice is disappearing, and if as usual there is no further inflow of water after the cold weather sets in then no more icicles form till spring. In some places ice caves have been used as natural refrigerators.

At Port Henry, N. Y., an iron mine noted for its summer ice was investigated by the Weather Bureau. While the temperature outside one August day was 66° F., that in the mine was 36° F. beside an enormous ice mass called the "iceberg." The mine roof had been opened by a great blast of dynamite so that entrance was at the apex of a conical hole 500 feet deep. Cold air collecting

in this cone funneled down into the mine and kept it cold, while warm air being lighter did not blow away the cold. Once in January a thermometer showed 38° F. below zero in the mine. Before the top was blown off, thereby allowing the entry of the cold air, the mine had been too warm for comfort.

"Sweating" Cellars. Cellars are proverbially damp in summer, and damper because the constantly urged remedy "Keep the cellar windows open" is adhered to. The rule should read "Keep the cellar windows open when the outdoor air is dry, but keep them closed when humidity is high."

The condensation on cellar walls and cold water pipes is owing to their coolness. The walls have the temperature of the ground at moderate depths, and that temperature is about the average annual temperature of the region in which the building is located. Thus, roughly, taking April air temperatures as guides, the wall temperature is from 40° to 45° F. from northern Minnesota, Ontario, Quebec, northern New York, through northern New England; 45° to 50° F. from South Dakota to southern New England; 50° to 55° F. from Nebraska and Kansas to the middle Atlantic coast; 55° to 60° from southern Kansas to Virginia, 60° to 65° from northern Texas to the Carolinas; and above 65° F. from the southern half

of Texas to southern Georgia and Florida. Cold water pipes have about the same temperature, because they enter the cellar from the ground.

Outdoor air often has so much moisture that its dewpoint is above the temperature of the walls. Therefore, while circulating through the cellar, the vapor is chilled and condenses upon the cool surfaces, leaving them damper than before. Thus, the better the circulation the damper the cellar.

The obvious remedy for sweating cellars is to open their windows only when the dewpoint of the out-door air is lower than the temperature of the cellar walls. The dewpoint may be found by stirring with a thermometer a mixture of tepid water and ice in a tin cup and reading the temperature when dew forms on the outside of the cup. As a rule days with northerly winds, and especially the nights, have dry cool air which readily falls into cellars to displace the warmer moist air.

SECTION X

MOUNTAIN WEATHER

Mountain Top Weather. The mountain top has its own weather, very different from that of the surrounding country. In the first place, it is cooler on the mountain, especially by day. Sometimes by night, however, it is warmer, even though the loss of heat from the ground is often greatest at the higher altitude, for the air cooled by contact with the cooled ground slides into the valleys, leaving the slopes and summit warmer than the valleys 1,000 feet or more below.

The wind blows harder on the mountain. By night local winds tend to blow down the slope, by day, up. The forced rising of warm air often forms clouds, which envelope ridge and peak, while it is clear in the lowlands, and for the same reason rainfall is greater, and thunderstorms very severe. The barometer is much lower, for it falls one inch for approximately each 900 feet of altitude, and with decreased air pressure the boiling point of water is lowered, which may be observed from the longer time required to boil food. Spec-

tacularly, a part of mountain top weather is the radiation fog which forms in the valleys below, oftentimes to dominate the landscape of the late night and early morning, appearing as an ocean of clouds, in which the mountain tops are islands.

Heat on Mountain Slopes. Mountaineers, including those who climb only the more lowly eminences in vacation country, occasionally experience a degree of heat while on the slopes, which does not afflict those whom they left behind in the valley below. Coupled with the warmth begot of violent exercise the effect may be disastrous upon the inexperienced climber.

The chief reason for such a heated condition of a mountain slope is the fact that the air is clear and permits the rays of the sun to reach the earth in nearly full vigor. Another and important reason is that the angle of slope under the hottest circumstances is such as to be practically at right angles to the line of the sunbeams, a condition, which, of course, results in a greater degree of heat than when the rays fall at an acute angle, just as the sun high in the heavens warms the ground more than when lower, even though the intensity of light on a surface held perpendicular to the rays may be the same.

When the crest of peak or ridge is reached the oppression disappears, nor would it be felt on the

slope away from the sun, even though no shadow were cast.

Mountain Clouds. The mountains have their characteristic clouds, chiefly because they stand as barriers in the paths of currents of moist air. The air must rise that it may ride over the summits, and this rising causes a reduction in temperature, often to below the dewpoint, which results in the formation of clouds. For this reason the rainfall and snowfall on the windward slopes of mountains are always greater than on the leeward slopes, especially where the winds blow from over the ocean or other large bodies of water.

From the same causes thunderstorms form frequently on the windward side of mountains. Warm, moist air is thrust upward in cumulating masses, condensation is very rapid and violent thunderstorms follow. One of the most severe forms of thunderstorm, however, occurs on the leeward slope. When thunderclouds pour cold air over the summit onto the warm air over slope and valley beyond, a thunderstorm of great violence may follow the overturning because of the great instability so produced. The mountain thunderstorm is one of the really appalling phenomena of nature, so frequent are the lightning bolts and so continuous the crash and roll of thunder.

The Brocken Specter. A strange phenomenon sometimes seen by people on mountains, and by balloonists and aviators, is the Brocken Specter. It consists of rainbow-hued ring or rings centered about the shadow of the head of the observer as cast, together with that of his mountain, balloon or airplane, upon a cloud mass. The name comes from the Brocken, a peak of the Hartz Mountains in Germany, where it is a common phenomenon.

The colored rings, or glory, as they are sometimes called, are similar to those of the corona, the bright bands of which are occasionally seen closely encircling the sun or moon. The colored rings encircle the shadow head, the smallest bluish, then yellow, orange, and red. Sometimes there is a double glory, that of larger diameter containing the full range of colors of the rainbow, from violet to red.

The cause of the Brocken Specter is what the physicist calls the diffraction of light, here, that light reflected from the interior of the cloud. It is unrelated to either the rainbow or the halo.

High Altitude, Low Pressure. The air pressure at sea level is about 15 pounds to the square inch, which in the United States serves to maintain a column of mercury at an average of 30 inches as measured by the barometer. But pressure decreases rapidly with altitude. To use rough fig-

ures, the mercury falls one inch for each 1,000 feet of ascent. Thus, for example, when the barometer stands at 30 inches on the seacoast, it is less than 24 inches on Mt. Washington, 6,300 feet high. The air pressure is 12 pounds to the square inch instead of 15.

An ordinary aneroid barometer, the kind with a clock face, placed in an automobile will give a crude estimate of altitude as one motors through the country. If the hand moves down the scale half an inch, say from 29.5 to 29, the ascent has been about 500 feet. Much closer altitude readings are readily possible with automobile barometers now on the market, which read in feet. Mountain climbers' aneroids have sliding scales to show altitude as well as barometer units.

Altitude and the Boiling Point. The higher you go the lower is the temperature at which water boils. To use an approximate figure the boiling point is lowered 1.8 degrees Fahrenheit for each 1,000 feet of altitude. Taking the familiar Mt. Washington as an example, while water is boiling at 212 degrees in Boston it is boiling at 201 degrees on the mountain top, a difference sufficient to affect cooking, for temperature being less, a longer time is required in cooking food or making tea. To take a more extreme case, on the Bolivian Plateau in South America, 12,500 feet

above sea level, it is impossible to cook potatoes by boiling, for no greater temperature than 190 degrees can be obtained in a kettle and this is insufficient. On Mt. Blanc, over 15,000 feet high, water boils at 185 degrees, and it is difficult even to make tea. People who have lived on the Bolivian Plateau must, on going down to the coast, guard against hot soups, lest they burn their mouths, so accustomed have they become to the lower initial temperatures of soups right off the fire, and to the more rapid cooling.

SECTION XI

THUNDERSTORMS

Thunderstorms. The thunderstorm is regarded by many as the most terrifying of all the phenomena of nature. To others there is a wild beauty in the great massing of clouds, the lightning bolts and crashing, rolling thunder, the tearing wind and deluge of rain.

In all of its features the thunderstorm is dependent upon the upthrusting of moist air, which we know as convection. When the moist air is rapidly elevated it expands, thus being cooled to a temperature below its dewpoint, causing abundant condensation of moisture into large raindrops and snowflakes.

The splitting of oversized raindrops results in lightning. Those drops that are carried high into the cold portions of the cloud mix with snow and freeze into hail. Local uprushes of the air produce tornadic whirls within the cloud. And heavy downpours of rain mark localized, descending currents of air. Outward from the base blows the squall wind, pushed out by the pressure of the cool, dense, descending air within the storm.

Typical Thunderstorm. One of the best related and most instructive descriptions of a heat thunderstorm ever written is the following by Willis I. Milham:

In the early hours of the afternoon, amid the horizon haze and cirro-stratus clouds in the west, the big cumulus clouds, the thunderheads appear. Soon distant thunder is heard, the lightning flashes are visible, and the dark rain cloud beneath comes into view. As the thundershower approaches, the wind dies down or becomes a gentle breeze blowing directly toward the storm. The temperature perhaps drops a little as the sun is obscured by the clouds, but the sultriness and oppressiveness remain as before. The thundershower comes nearer, and the big cumulus clouds with sharp outlines rise like domes and turrets one above the other. Perhaps the loftiest summits are capped with a fleecy-like veil which extends out beyond them. If seen from the side, the familiar anvil form of the cloud mass is noticed. Just beneath the thunderheads is the narrow, turbulent, blue-drab squall cloud. The patches of cloud are now falling, now rising, now moving hither and thither as if in great commotion. Beyond the squall cloud is the dark rain cloud, half hidden from view by the curtain of rain.

The thunderheads and squall clouds are now just passing overhead. The lightning flashes, the thunder rolls, big pattering raindrops begin to fall or perhaps, instead of these, damage-causing hailstones. The gentle breeze has changed to the violent outrushing squall wind, blowing directly from the storm, and the temperature is dropping as if by magic. Soon the rain descends in

torrents, shutting out everything from view. After a time the wind dies down but continues from the west or northwest; the rain decreases in intensity; the lightning flashes follow each other at longer intervals. An hour or two has passed; it is growing lighter in the west; the wind has died down; the rain has almost stopped. Soon the rain ceases entirely, the clouds break through and become fracto-cumulus or cirriform; the temperature rises somewhat; but it is still cool and pleasant; the wind has become very light and has shifted back to the southwest or south. Now the domes and turrets of the retreating shower are visible in the east; perhaps a rainbow spans the sky; the roll of the thunder becomes more distant; the storm has passed, and all nature is refreshed.

Artificial Thunderstorms. Thunderstorms form at times in connection with great forest fires and often over volcanoes. The intense heat so expands the air that it is forced up rapidly by the heavier air near by. As it ascends, it cools, following the natural law. The hot air and smoke, if there is enough moisture, eventually reach a height where condensation of water vapor begins, and a cumulus cloud forms, soon followed by the towering cumulo-nimbus, or thundercloud. The effect is the same as that of a day of extreme heat in summer, when the air is still and humidity high. In this way a forest fire conceivably may create the deluge which extinguishes it. Storms

formed by the heat of volcanoes are occasionally of terrific violence, and are a cause of the deluges of hot mud that sometimes overwhelm villages and cities.

The story is told of a party of engineers working in a Florida wilderness with negroes as helpers. The negroes being very hot and not caring to cut through a sawgrass swamp, the engineers determined to impress them and announced that they would create a cooling thunderstorm. The jungle of tall grass with its several feet of accumulated dry matter was fired, and, presently, the great volume of highly heated air which ascended, caused cumulus clouds to form and grow rapidly into thunderclouds; lightning began to flash, and thunder to roll, and torrents of rain to descend. Of course, this could not have happened were there not already nearly enough moisture and heat for natural convection to make a shower.

The Two Kinds of Thunderstorms. There are two common types of thunderstorms, one, the local, or "heat" thunderstorm, generally small and ephemeral, and at times leaving the atmosphere fully as oppressive, if not more so, than before it occurred; the other the "windshift line" type which marks the arrival of drier and cooler, clear weather. The local shower is generally con-

fined to the late afternoon and early evening, closing the hours of the day's extreme heat. An unstable condition is brought about by the overheating of the surface air when the atmosphere is comparatively quiet. Such storms are sporadic, and may move in any direction, though usually from a westerly direction.

The other class of thunderstorm, as a rule, is more severe. They may form a nearly continuous line hundreds of miles long across the country, as the cool air from the west or north meets the hot, moist current which has been rendering the atmosphere trying to man and beast. The cool current usually strikes the side of the warm current like a wedge, either lifting the moisture bodily or entrapping it by entry above, then descending and violently forcing it aloft. Condensation takes place rapidly, resulting in disruptive electrical disturbances and a heavy downpouring of rain. This type of storm often shows the forbidding anvil-shaped cloud, and is not infrequently accompanied by hail and windsqualls which sometimes are of such strength as to level trees and frail buildings. Its arrival may be either by day or by night.

Lightning. The phenomenon of lightning, most impressive of all electrical manifestations, long remained without satisfactory explanation. Only

comparatively recently has science, with the aid of delicate instruments, come to conclusions which stand the test. Electricity always exists in the atmosphere; every molecule of dust and droplet of moisture has its charge. Lightning is a manifestation of enormous charges of opposite kind in relatively close proximity.

Such great charges arise in violent convection as a result of the splitting of overgrown raindrops and the winnowing of the smaller from the larger fragments by the strongly rising air. Lenard found that the spray blown up a waterfall by a breeze is negatively charged, while the large drops rapidly falling to the bottom of the fall are positively charged. The same phenomenon occurs on a grand scale in a thunderstorm.

Raindrops form, always growing larger and larger, but cannot fall against the force of the powerful ascending air currents. Finally, the drops become so large that their limit of cohesion is passed and they break up. The larger drops remain in the levels of the cloud base or descend to earth, while the smaller pass up into the cloud-tops. The larger drops carry a positive charge, the smaller ones a negative one. The earth usually is negative. Thus we have a positive charge between two negative charges. These charges become more and more powerful, and finally the dif-

ference in potential becomes so great that a discharge occurs, from cloud to cloud, or cloud to earth. The length of the flash from cloud to earth is usually but a fraction of a mile, though sometimes three or four miles, but with short jumps from cloud to cloud a single chain of lightning may extend as much as 20 miles.

Four Kinds of Lightning. Lightning is popularly divided into four general classes. That of most common occurrence, which one always associates with the thunderstorm, is the "zigzag" flash or forked lightning, where electrical discharges disruptively break their way by the easiest devious routes through the air. The crooked path is that of least resistance. The second class is the "sheet" lightning, which is the sudden, brief lighting up of a sheet of rain or a whole cloud, with outer edge sometimes more brilliantly illuminated than the center. The cause is a hidden flash.

A third form is "heat" lightning, which is the term applied to the sudden lighting up of the atmosphere near the horizon, occurring even when no thunderclouds are visible, and is usually explained as the reflection from the hazy air of the lightning flashes of storms below the horizon. It is called heat lightning because it is characteristic of hot weather when local thunderstorms occur.

The fourth form is ball lightning, which is rarely seen, but is admitted as a real phenomenon, although accounts of it are often exaggerated. The lightning appears as slowly moving balls of fire, which in many cases burst with a loud explosion.

The common lightning bolt may be discharged from a cloud at frequent intervals. When the distance traversed by the flash is relatively small, it may appear to the eye as a straight line, as commonly happens when a storm passes up over a mountain slope, and bolts are projected with startling and terrible brilliancy.

Air Expansion Makes Thunder. Thunder is produced by the violent expansion of the air caused by the tremendous heat of the lightning. Immensely powerful waves of compression are set up, similar to those following the discharge of a cannon. In fact, just as the gun's explosion may injure objects by the concussion of the waves which pass from it, so, too, do the compression waves from a thunderclap sometimes inflict damage on fragile objects near by.

The accepted theory is that thunder is due wholly to the explosive expansion incident to extremely sudden and great rise in temperature. The waves are heard as a single crash when the bolt is straight and short. But if the path be long and forked, as in the irregular "zigzag" flashes,

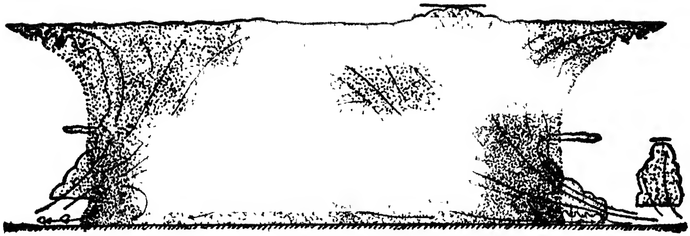


FIG. 24. DIAGRAMMATIC CROSS-SECTION OF A LOCAL, OR HEAT, THUNDERSTORM. The essentials of a thunderstorm are great currents of rapidly rising moist air, forced upward by a downward and outward spreading wedge of cooler, much denser air, inside the cloud, as well as by the descending, cooler, heavier air outside the storm cloud. In the diagram the dotted line separates the upward currents above from the downward and outward ones below. The continuous lines, not arrows, represent outlines of the cloud mass. This mass is flat on top because of a ceiling of warmer air. At one place there is a protrusion into this ceiling where the upward motion of the air and its inertia are so great that the ascent went well above the level of equilibrium. In this same region of the storm, is represented the formation of hailstones, from raindrops carried aloft and sustained by the strongly rising wind. The distribution of small dots over the diagram is an attempt to show the distribution of raindrops. Especially heavy rainfalls are represented at the forward (right) and rear (left) margins of the storm, where intense condensation and concentration of rain streaks by the wind are operative.

On the front and rear of the storm are shown the outspreading top shelves of cloud with their heavy, mammato-form, or downward protuberances. An intermediate moist layer is marked by a thin cloud shelf, and at the bottom are the outward growing squall clouds. That on the front of the storm (on the right), where the winds are strongest, is most developed. The lowest outward projection of cloud is the great, dark, storm collar, or squallcloud, that is seen onrushing just before the storm breaks. It is but a small part of the whole storm, towering to miles above, and miles and miles beyond. With such an enormous dense cloud mass it is no wonder that the lower air becomes so dark with the arrival of a thunderstorm. The small cloud on the extreme right is a secondary cloud, which may grow into and join the main cloud-mass. (For acknowledgment, *see* legend of FIG. 23, p. 113.)

there is a succession of crashes or rumbles; for while the flash is practically instantaneous, the several explosions occurring at different distances register at different moments. The rolling of thunder is at times caused, in addition, by reverberations, as the sound echoes back and forth between eminences.

Thunderstorm's Squallcloud. One of the awesome phenomena of the thunderstorm is the squallcloud, showing as an onrushing, dark gray arch, spanning the western or northwestern sky against a blue-black background of falling rain. Sometimes it is called the "storm collar." It is the forward projection of the lower portion of the thunderstorm cloud, and is overshadowed by the forward-spreading, dense cloud sheet above.

As it approaches, the raggedness of its lower edge becomes noticeable, and at once a rapid upward motion of flecks of dark cloud joining the body of the cloud is evident. Wisps suddenly appear and rush into the low cloud. Now the arch has reached the zenith and spans the sky in both directions; at once the dead calm is broken by a swirl of dust as the front of the cool squall arrives. The trees, looking vividly green against the dark-blue background, bend away from the approaching darkness and the growl of the thunder. Scattering raindrops begin to fall. Overhead the

sky is like a boiling cauldron. Great rounded masses of cloud are descending. Now and then a ghost cloud slips by with a passing gust. The darkness gathers. Soon vivid lightning and the almost immediate crashes announce the main front of the storm. The rain begins to fall in torrents and the squallcloud is lost to view.

The Destructive Thundersquall. The outrushing wind of the thunderstorm, consisting of the cool air which has descended with the mass of falling rain is sometimes strong enough to flatten anything in its path. Its velocity rises at times to hurricane violence. When it reaches the bottom of its descent in the cloud it is much colder and therefore appreciably denser than the warm air outside the storm. Being heavier the cool air gravitates outward, and running under the warm air lifts it and makes it flow back toward the thundercloud, thus assisting in adding to the storm's volume.

The force of the squall in front of the storm is not due merely to this outflow. Combined with it is the forward motion of the descending air as it comes down with the cloud, imparted to it by the onrushing motion of the storm mass. When thunderstorms are most intense they are often moving most rapidly, being carried by the wind in which the body of the storm occurs. Air descending from

the level where the wind is strong retains its strength, except for some losses by friction, and rushes over the ground. Thus the outward and forward motions are added together. The sum total may, rarely, be a destructive power comparable to that of the hurricane or tornado. Behind the storm the outflow and forward motions tend to neutralize one another, and there is no outward wind, excepting where the storm is moving slowly.

Hail is Hot Weather's Ice. Hail is a phenomenon of spring and early summer in the South, and of spring and summer in the North. It is a feature of intense thunderstorms, and consequently occurs in hot weather and practically never falls in winter. Sleet is an entirely different formation, being small and without layer structure. Only when the freezing temperatures are within reach of convection and the surface temperatures high do we have hail.

When convection is most violent, and air currents are ascending at the rate of 25 or 30 miles an hour, raindrops are caught in the uprushing air and carried high up into the cloudtops. These, under such atmospheric conditions, tower into the regions of extreme cold, where the temperature is far below freezing, and often even below zero. On mixing with snow they freeze as globules of cloudy ice. Getting into descending

currents, out of the uprushes, they fall into the rain levels, and take on a clear layer of ice from contacts with rising drops; then again the growing hail is tossed on high, to receive another coat of snowy ice. This process is sometimes kept up until on rare occasions stones with 25 layers and as big as baseballs result, such as those falling at Annapolis, Md., June 22, 1915.

When the upward wind pressure is removed and gravity is permitted to work its will, then the hailstones fall to the earth, seldom doing greater damage than to cut up growing things, because the stones are small. But sometimes the great stones are a serious danger; they play havoc with crops, even to the point of complete ruin, destroy light structures and glass everywhere, and even kill cattle in the fields.

Icy Wind Makes Summer Hail. Occasionally an icy wind sliding over us at a height of two miles, may become the cause of a thunderstorm accompanied by hail in such quantities as to cover the ground like a winter snowstorm. The only warnings may be the formation of a double layer of clouds, as the cold mass comes in contact with the warmer air above and below it, and perhaps a rise in barometer due to the greater weight of a cold layer of air a mile thick, as compared with that of the warmer air which it displaced.

From the lower sheet tall clouds known as turreted alto-cumulus raise their rounded tops, so high, perhaps, that a mile above their base they flatten out against the ceiling where the cold air meets the warm above. Each is a column relatively slender at the middle, with spreading base and top. Sometimes a row of them extends across the sky like a titanic balustrade.

These clouds are usually densest in the early morning, after the cooling overnight, but the morning sun evaporates and thins them, usually to such an extent that the hot rays penetrate through to the ground and warm it and the lower air. Ascending currents quickly form and, moving rapidly, penetrate the cold layer, where the heavier air about them forces them violently upward. If the ascending air is humid intense condensation takes place and a thunderstorm forms. The raindrops, carried by the uprushing air high aloft into the intense cold, mix with the abundantly forming snow and make hail, which, becoming too heavy for the updraughts to sustain, falls to the earth. The air descending with the hail is kept so cold that snow may accompany it, and on higher land may rarely even reach the ground.

The Terrible Tornado. The tornado is caused by the same influences which produce hail, in other words the most violent type of convection, the ex-

treme of the turbulent vertical overturning of the atmosphere when the air next the earth is muggy. Giant forces are present in the making of the cloud masses, and a vortex generates on the same principle as an eddy in turbulent water. Not always does this vortex reach the earth, but when the whirl becomes most violent in its gyratory motion, the funnel-shaped cloud stretches down until the writhing tip comes in contact with the ground. The tornado is to the land what the waterspout is to the sea, only on the land the visible funnel is a cloud of dust, water drops, and debris. A partial vacuum is produced in the center of the whirl, and the low temperature which results generates an elephantine trunk of cloud which first makes the tube visible; the low pressure explodes air containers such as houses, and the wind about the vortex prostrates every obstacle. The velocity of this wind has never been measured, but judging from monuments and bridges moved, it is believed to reach even 500 miles an hour.

The one fortunate thing about the tornado is that it is small, averaging roughly 1,000 feet in diameter, and sometimes only a few feet. It travels generally from southwest to northeast at a rate of from 20 to 50 miles an hour, and with an average length of devastation of 25 miles. At times the funnel may seem to leap, as its end

ceases to reach the ground, so that places in its path may be untouched, where in both directions stretch scenes of destruction and desolation.

The Gulf states experience their tornadoes usually in winter or early spring, the northern states in spring and summer, when windshift line contrasts are greatest and temperatures high. The southern margin of a tornado is more dangerous than the northern because there the wind has combined progressive and rotary velocity. The way to seek safety from the oncoming tube is to run for dear life to the northwest. A few feet may make the difference between dire peril and complete safety.

Thunderstorms Do Not Return. Sometimes a thunderstorm appears to return. It is here in all of its fury, it passes on, and presently it is here again, delivering more rain, more wind, more thunder and lightning. But, as a matter of fact, it does not return; it continues on its way. Additional cloud masses have formed at its rear to bring the rain and electrical discharges which seem to be a return of the initial storm.

The core of the thunderstorm consists of a heavy current of cold air and rain descending from aloft. This chilled air spills out from under the cloud bulk, forming a moving barrier against

which the warm moist wind then prevailing acts exactly as it does when it strikes a mountain range. It rides rapidly up the side of the barrier, and in so doing expands and thereby is cooled, causing rapid condensation to take place. As the main mass goes forward, new thunderclouds form with incredible rapidity at the rear. The effect is as if the storm were returning.

The Parting Bolt of Lightning. On rare occasions, sometimes after a thunderstorm has passed and the rain has ceased, a lightning bolt descends without warning. Usually it is a bolt of extreme severity, a blinding flash even when in the bright sunlight, as sometimes happens, and accompanied by a deafening crash. Such a bolt occasionally demolishes a large tree and kills persons under it.

The cloud from which this lightning comes is the rear portion of the far-flung spreading top of a storm of great intensity, the center of which may be miles away. It is characteristic of heavy thunderclouds that they mushroom out like a vast-spreading umbrella. When their electrical charges are powerful they may let loose a bolt which will reach the earth, though it must jump a gap of four or five miles. Such a bolt is, of necessity, of particularly destructive force, for the difference in potential between cloud and earth must be enor-

mous, even when compared with that of the usual jump of a mile. The thunder may be heard 20 miles away.

Coast Thunderstorms. Regions along the Atlantic seacoast where the expanse of land is small as compared with the neighboring ocean, have practically no heat thunderstorms. Convection, which is the vertical interchange of the warm air at ground level with the cool air aloft, cannot take place with sufficient violence for the formation of cumulus clouds on a large scale, because the heating surface of the ground is so insignificant as compared with that of the sea. Cape Cod is typical of this condition. Its land surface is very small. Consequently, such cumulus clouds as do form cannot grow into cumulo-nimbus before the immediate supply of warm air is exhausted. Clouds of this type may float over from the mainland, but not in the formidable proportions of the thundercloud, even when storms are forming inland.

But Cape Cod and other similar regions have their "tempests," as Cape Codders call them. For they experience thunderstorms of the line type, just as people do inland or on the ocean. This is the thunderstorm that comes with a sudden change of weather following the usual hot spell. The wind, blowing from the southwest, transports the

vapor from the Gulf Stream, and humidity is high. A "high" arrives, heralded by a cool wind from the west, northwest, or north. Its denser air strikes the warm southwest current like a wedge and lifts it aloft, or falls over it from above, causing the rapid condensation that quickly breeds thunderstorms, often of extreme violence. These storms pass across the country in a belt sometimes several hundred miles long north and south, forming constantly at the line of contact between the warm and the cool wind. The coasts get them in common with inland regions. The greater intensity claimed for these storms in such regions as Cape Cod is probably partly imaginary. They seem more intense to persons to whom a thunderstorm is more of a rarity than it is to people living inland. However, their winds, blowing with open sweep across the water, may be stronger than on the mainland.

Distribution of Thunderstorms. The distribution of thunderstorms varies greatly between different parts of the United States. Thunderstorms are numerous in mountain country because mountains favor strongly rising warm winds by day. Pikes Peak, for example, has a thunderstorm almost every afternoon in summer. Wherever the air is sufficiently warm and moist thunderstorms may be created by convection. Regions which are

often overrun by very humid air from the Gulf of Mexico or the Gulf Stream have them almost daily. Tampa, Fla., in summer has a thunderstorm two days out of three, with an average of nearly 100 a year.

The East Gulf states in general have the greatest number of thunderstorms, with a yearly average of 60 thunderstorm days. The average is over 50 from Kentucky and Iowa southward, and over 30 south of a belt from western New Jersey and western New York to southwestern Montana. Neither cool air, as near the shores of the Great Lakes or the north Atlantic coast, nor dry air, as in the western plateau region, favors thunderstorms. In eastern New England, practically all of Canada, and most of the region west of the Rocky Mountains, except in New Mexico and Arizona, the average number of thunderstorm days is less than 20. On the Pacific Coast thunderstorms are very rare.

SECTION XII

THUNDERSTORMS AND THE VACATIONIST

Fourth of July Weather. Independence Day comes in the period when summer's maximum heat is approaching, and when, too, the air aloft is still somewhat cool, not having been fully heated since winter and spring. The hotter the weather the greater the likelihood of a thunderstorm, especially when the higher levels of the atmosphere have not become heated. Then, too, there is the chance of the passing of a windshift line, which, in summer, often means a line of thunderstorms passing across the country. Still another foul weather hazard is the possible northeaster or southeaster to put a damper on every outdoor activity. Yet, in spite of the possibilities, the glorious Fourth is more frequently fair than otherwise. The chief danger lies in the local heat thunderstorm, which, as a rule, is confined to a comparatively brief interval of the late afternoon or early evening.

If the morning of the Fourth is hot and muggy and the air still, the chance of the thunderstorm in the late afternoon, following the hours of ex-

treme heat, is very good indeed. On the other hand, if the morning is warm, but with life in the air, which means not too great a moisture content, then the chance is slight.

Rain Insurance. Scientific weather observations have come to be of great material value to business. They are the basis for warnings of frosts, rains and floods, and storms which threaten shipping. One of the latest aspects of their usefulness is in connection with rain insurance. Companies now undertake to insure against loss by rain due to the interruption of outdoor events, such as athletic games and agricultural fairs. The referee is the weather observer. The criterion as to whether rain does or does not inflict loss is usually specified as a fall of one-tenth of an inch during a particular period of hours set by the insured. If less falls, the insurance company wins; if one-tenth inch or more, the insured receives the amount of the policy. The rain gage of the observer is the arbiter.

July 4 is the great rain insurance day, because so many outdoor events are scheduled. One policy may protect from 5 to 11 a.m., another for the whole day, yet another for specified hours in the afternoon, and a fourth for a period of the evening. Under such conditions the observer and his rain gage have a busy time, if there is rain, espe-

cially if it be showery. The companies may win in the morning and lose in the evening, the insured may win or lose by a smallest fraction of an inch of water. If the amount is in doubt on a given policy, if the claim might be made one way or the other that the observer's figures are incorrect, then the contents of the rain gage are removed to a bottle for exact measurement with laboratory methods.

July 4 has an evil reputation for rain. The rainy day or the terrific shower which spoiled the fireworks is remembered. The fair weather Fourth makes no strong impression. There are more rainless Fourths than there are rainy; otherwise insurance premiums would be prohibitive.

How to Test for Thunderstorms. Persons such as farmers in harvest time, or campers and picnickers who are anxious on bright, warm, summer mornings to know the likelihood of a thunderstorm before night, may get much assistance from a shiny metal cup or a thin glass filled with water, a lump of ice, and a thermometer.

The water should be lukewarm at the start. Then put in the lump of ice and stir with the thermometer. By and by the outside of the vessel will begin to "sweat," due to the condensation of the moisture of the air on its cold surface. When this happens, observe the temperature of the

water. That temperature is what is known as the "dewpoint."

If the dewpoint is above 65° F. it indicates that the air has abundant moisture, which under ordinary circumstances, in combination with a hot sun, is quite likely to mean the breeding of one or more local heat thunderstorms in the afternoon. Generally speaking, if the dewpoint is above 70 in the morning a thunderstorm is likely to develop before night. On the other hand, if the dewpoint is found to be relatively low, say below 60° F., the amount of water carried by the air is small and a thunderstorm is unlikely.

Distance of Lightning. The distance of lightning from the observer may be quickly calculated from the lapse of time between the flash and the hearing of its accompanying clap of thunder. Light travels so rapidly that the flash registers on the eye almost instantaneously. Sound travels only about 1100 feet a second, or approximately a mile in five seconds. Therefore, counting the seconds elapsing between the flash and the thunder makes reckoning of distance simple. A second is easily counted by saying some such words as "One chimpanzee" moderately fast; a few experiments with a watch will give accurate rhythm. This method is used by many photographers in determining exposures.

Thunder may be heard a distance of 10 miles, rarely more than that excepting under most favorable conditions, when the distance may exceed 20 or even 30 miles. Ten miles means a lapse of about 50 seconds from the instant of the lightning flash.

Finding Thunderstorm's Course. When a thunderstorm is observed in the distance it is not difficult to determine the direction of its path, whether it be retreating, or moving at right angles to the line of vision, or approaching the observer directly or obliquely. If the storm's distance is increasing the apparent size of the clouds will dwindle. If it is passing off at right angles the motion will be noted easily, while the size of its clouds will diminish very gradually. If it is approaching obliquely, the clouds will rapidly become bigger and more menacing, but the lateral movement will be observed. If it is coming head on, to cover in its path the point of observation, the storm will loom bigger and bigger, and there will be no movement sideways, excepting as additional cloud masses accumulate on its flanks. To ascertain the course of the storm, line up the distant cloud with some fixed object, such as a post or tree, and watch it for a few minutes. Thunderstorms generally have a quick movement; they usually travel 25 miles an hour or faster. It does

not take long to discover the direction of their passage.

When a storm is seen approaching obliquely, apparently to pass to one side of the observer, he should not be too sure he will escape. Thunder-clouds build quickly. They pass through an atmosphere in which are present the same conditions which admitted the formation of the initial storm mass in tumultuously rising, warm, moist air. Therefore they take unto themselves new cloud formations, which may spread out their fronts greatly. If an oncoming storm which is aimed to pass, for example, well to the right of the observer, is seen to be extending its mass on its nearer side, then it is not unlikely that before it has traversed the separating miles its front will have expanded to include a much broader strip of territory. Too confident a sense of security may result in a good wetting.

Timing Thunderstorm's Arrival. When a thunderstorm is seen in the distance directly approaching, then the moment when the observer will feel the first gust of cool wind and the first big splashes of rain may be estimated quite closely. He must accept two averages, the one the height of the thundercloud base as one mile, the other the speed of travel as 25 miles an hour. These are close enough for ordinary purposes.

Hold a rule or pencil in the right hand, supported vertically between the thumb nail and the bend of the forefinger. Holding the pencil at full arm's length, keeping head erect, get some one to measure with a yardstick the distance from the eye to the pencil, which, with most adults, is between 20 and 24 inches.

When the thunderstorm comes into view hold out the pencil, and shift it up and down until the distance from its upper end to the thumbnail covers the space between the base of the cloud and the horizon line, which, if the actual horizon is concealed, as it usually is in rolling or hilly country, may be taken as a point level with the eye.

Accepting the height of the base of the thundercloud as one mile, its distance in miles is the ratio of the height-of-pencil measurement to the eye-to-pencil distance. If, for example, the height-of-pencil measurement is 3 inches and the eye-to-pencil distance 24 inches, the ratio is 3 to 24 or 1 to 8, and the distance of the approaching storm is 8 miles. If the height-of-pencil distance is 2 inches, the ratio is 1 to 12, the distance of the storm being 12 miles.

Accepting the average speed of the approaching storm as 25 miles an hour, if it is 8 miles away it is due to arrive in 20 minutes; if 12 miles away,

in about half an hour. Of course, these results are only roughly approximate. But in any case, the simple method will tell whether the storm is close at hand or a long way off.

Timing Distant Thunderstorms. Thunderheads are very often seen so far away that their flat bases are hidden by intervening elevations or are actually below the horizon. In such cases the distance of the storm and, if it is approaching, the time of its arrival, may be closely estimated by the use of a measure or pencil, in the same manner as that employed where the cloud base is used. The pencil or measure is held upright in the bend of the forefinger, supported firmly by the thumbnail. The arm is held at full length and the distance measured from the eye to the pencil. The pencil is shifted up and down until the distance from pencil end to thumbnail covers the space between the level of the eye, taken as the horizon, and the summit of the tallest turreted cloud which is assumed to be four miles above the ground, instead of the one mile employed when the base of the cloud is considered.

The ratio of the height-of-pencil measurement to the eye-to-pencil distance determines the distance of the storm.

Thus, assuming the height-of-pencil measurement to be 3 inches, and the eye-to-pencil distance

24 inches, the ratio is one to eight, which, with the 4-mile cloud height, gives a distance of 32 miles. Or, if the height-of-pencil distance is 4 inches, the ratio being 1 to 6, the distance is 24 miles. Assuming the rate of travel of the storm to be 25 miles an hour, a storm 32 miles away, if approaching the observer directly, should arrive in not over 1 hour and 20 minutes; a storm 24 miles away in about one hour.

Lightning Measures Storm Speed. The interval between a lightning flash and its thunder-peal may be employed not only to determine the distance at which the bolt struck, but also to give the rate of travel of the storm and the time of its arrival. The measure of distance between flash and thunder crash is 5 seconds per mile. The flash reaches the eye practically instantly; the sound of the thunder travels about 1100 feet per second.

To determine the speed at which a storm is approaching and the probable time of its arrival, take two observations. Measure the time between an intense flash and its following thunder. Five minutes later, by the watch, time another bright flash. If the interval in the second case is shorter than in the first, the storm is getting that much nearer.

Let us suppose that the first observation gives

an interval of 40 seconds, which at 5 seconds to the mile means a distance of eight miles to the active front of the storm. The second observation gives an interval of 30 seconds, which means the storm is six miles away. Consequently the storm has traveled two miles nearer the observer in five minutes, or at the rate of 24 miles an hour. It is still six miles away. At this rate of progress the remaining six miles will require 15 minutes. Naturally, this method gives only approximate results. Yet there are occasions when it is worth while to know, even roughly, how much time remains before the torrents will begin to descend.

Safety in a Thunderstorm. Hazard in a thunderstorm is never great, as statistics prove, yet hazard always exists. A person is safer in some places than in others. A modern steel office building, a structure like the Eiffel Tower in Paris, a steel ship, all are practically lightning proof, so far as human occupants are concerned. The current follows the steel shell; a bolt may strike the structure and those within it never be aware of it. It is safer to be in a house than out-of-doors.

In the open one should avoid high ground and especially isolated trees and the edges of woods, particularly on the side from which the storm is approaching. Low trees well within a wood, but not close to any exceptionally tall trees are

much less dangerous than trees in the open. Caves or ground caverns of any sort are comparatively safe. When lightning is very severe even sitting or lying in a ditch, however uncomfortable that might be, is recommended. Above all, avoid the hillcrest, the wire fence and the isolated tree.

The Motor in a Thunderstorm. An automobile is not the safest place in which to be during a thunderstorm. The rubber tires which, in dry weather, very efficiently insulate a car from the ground against an ordinary electrical charge, offer no appreciable protection against the enormous potential and violence of lightning. This is not the real hazard of the automobile, however, in a thunderstorm. The danger comes either in the open, or when a car is parked beneath a tall tree or close to a wire fence. The latter is a real source of danger, for it can carry a deadly current a long distance from the point where the bolt struck it.

The wise thing for the motorist to do in a thunderstorm is to stop, if possible, somewhere below the general level of the ground, away from tall trees or a wire fence. A spot where the road cuts between high banks would be as good as any.

Lightning Rods. The lightning rod agent of other days placed such a stigma of disrepute on this protection against lightning bolts that only

recently has it regained the confidence of the public. The fact has been demonstrated scientifically and by the compilation of statistics that the building with a properly installed lightning rod system stands far less chance of being struck than does a similar one which is unprotected. Moreover, if the protected building is struck the chance of fire or other serious damage is reduced to a small minimum.

The conductors, preferably copper, should be grounded deep down where there is permanent dampness. They should not be near the telephone line and other metallic conductors.

The lightning rod serves two purposes. Its chief function is to afford an easy path to the ground for any bolt which strikes the building. A minor usefulness is to provide an efficient means to facilitate the nearly constant interchange between the electricity of the earth and that of the atmosphere. This quiet discharge possibly may serve so to reduce the difference in potential between earth and clouds as to lessen the probability of the launching of a bolt at this particular point instead of at another near by.

Thunder Does Not Sour Milk. It is often said that a thunderstorm sours milk. The lightning and thunder, however, really do not affect the milk at all. It appears, rather, that hot, moist weather

which produces heat thunderstorms, also favors bacterial growth and the spoiling of food. On a hot day the ice-box temperature will probably be higher than usual, unless particular care is taken to replenish the ice. During the day the lactic acid bacteria in the milk will multiply more rapidly than usual, so that by evening milk which tasted all right at noon may be distinctly sour. Now heat thunderstorms commonly occur in the late afternoon; therefore, we may say that the milk was soured by the thunderstorm, and jump at the wrong conclusion. The process of souring had been going on all day, favored by the thunderstorm conditions, not suddenly evoked by the storm itself.

SECTION XIII

WEST INDIAN AND OTHER HURRICANES

Hurricane Season. The season of West Indian hurricanes, most destructive type of storms, begins in July or August. Such disturbances seldom occur excepting in the late summer and early autumn. They are cyclones of an intensity exceeded only by the tornado, but instead of being a few rods in width, their path of destruction may cover several hundred miles. They differ from the typhoons of the China Sea in name only. An average of about five annually are known to occur in the West Indian region. While most of these touch some portion of the Gulf or Atlantic states, an average of less than one a year is severely destructive.

Such a hurricane caused the Galveston horror of Sept. 8, 1900, when 6,000 lives were lost as a result of the frightful wind and its accompanying flood of sea water and terrific storm waves which pounded through the city from the Gulf. Even more intense was the hurricane of Sept. 29, 1915, which swept the lower Mississippi Valley, the indicated wind velocity attaining 130 miles an hour.

Hurricanes originate in the tropics somewhere north of the Equator, breeding over calm, warm waters under the nearly vertically, blazing sun. They move in a west-northwesterly direction until they reach the latitude of westerly winds, when they recurve and move in a northeasterly course. Some hurricanes recurve before reaching the Florida coast, in which case they may not even be noticed on land. Others advance until on the recurve they cross the Gulf of Mexico, when the storm center may pass over the eastern United States from the Gulf to the St. Lawrence Valley, gaining speed of progress as it advances. While their intensity diminishes over the land, they usually continue to bring flooding rains and high winds.

Earthquakes and Storms. The coincidence of earthquakes and intense cyclones has often been noted. Where conditions are ripe for an earthquake the earth's crust is in an unstable condition. It is barely possible, though not yet proven, that the stresses accompanying the passage of a severe cyclone may be sufficient to initiate a quake.

It is clear that tropical cyclones subject the earth's crust to an appreciable and relatively sudden strain especially on coasts. A drop of two inches in barometric pressure means that a load of about two million tons is removed from each

square mile of land, while over the neighboring sea, a 10-foot rise of water, commonly associated with such a storm, would add about nine million tons less two million tons for reduced air mass, or seven million tons per square mile of sea-bottom. When a tropical cyclone passes, a differential pressure of, say, nine million tons per square mile on land and sea-bottom is created and dissipated within relatively few hours.

A typhoon, or tropical cyclone of the Pacific, commenced at Yokohama just before the great earthquake and affected Tokio soon after. The winds of the typhoon made the fires terribly destructive to life and property. Refugees fleeing to windward found themselves to leeward of the flames as the wind shifted while the typhoon passed. Unfortunately the storm center did not come close enough to give rain.

Cirrus Spokes. Cirrus spokes seem to radiate from the center of a great storm like a hurricane or intense thunderstorm, and sometimes their appearance in the sky is the first warning of the approach of the dangerous disturbance. They appear to converge in a more or less dense cloud on the horizon. They are formed by the outward movement of cloudy air, though all those visible at one time are moving in nearly the same direction. Only when the storm is relatively small, as

in the case of the spreading top of a local thunderstorm, are true divergences visible. The nearly parallel though actually slightly radiating streaks of cloud seem to come from a common point just as the rails on a long stretch of straight track seem to come from a point. If the point of convergence remains the same for some time it is reasonably presumed that the storm is coming toward the observer, especially if the clouds get denser and denser.

Equinoctial Storms. One of the most widely accepted of weather beliefs is that the physical result of the sun crossing the equator is a severe storm, and for that reason such a disturbance is always looked for at the spring or autumn equinox. It has come to be known as the equinoctial, or line, storm. The arrival of the seasons themselves are not alluded to with greater confidence.

That there is likely to be a severe storm in the early autumn is not disputed. Storms occur at frequent intervals over the North Atlantic throughout the cold months, from September to March, and occasionally such a disturbance coincides with the autumn equinox, usually September 22. It is as likely, however, to come earlier or not until October. There is usually a West Indian hurricane about this time, for it is the height of the hurricane season in the Gulf of

Mexico, and these storms sometimes pass up through the United States with sufficient violence to give strong winds. Likewise, about the time of the spring equinox winter may furnish one of its storms, as a farewell demonstration of its turbulence. But the sun's immediate passage across the equator has nothing whatever to do with it.

Waterspouts. Waterspouts are most common in the warmer and calmer seas of the tropics, but they are by no means unknown in the waters that touch the shores of the United States for they may occur wherever violent thunderstorms are found. A famous instance was the beautiful waterspout of Oak Bluffs, Mass., then called Cottage City, on the island of Martha's Vineyard, on August 19, 1896, which passed in view of thousands of people. This one was in conjunction with a line thunderstorm, caused, perhaps, by the overrunning of the hot, moist surface air by a layer of cold air.

Waterspouts are simply tornadoes which occur over bodies of water; as is abundantly proved by the fact that whenever a tornado crosses a lake or river it instantly becomes a waterspout, and a waterspout which runs inland develops at once all the characteristics of the tornado.

The phenomenon is accompanied by a powerful updraught of air, so strong that it whisks up the

Fig. 25. Tornado near Elmwood, Nebr., Apr. 6, 1919. (W. A. Wood.) The funnel cloud marks the position of an air whirl so violent that its centrifugal force causes considerable cooling by expansion and thus makes a cloud. *See* pp. 138-140.

Fig. 26. House near Blevins, Ark. Demolished by tornado of Apr. 15, 1921. The family of father, mother and 11 children escaped serious injury by lying on the floor between two beds which held the walls off them.

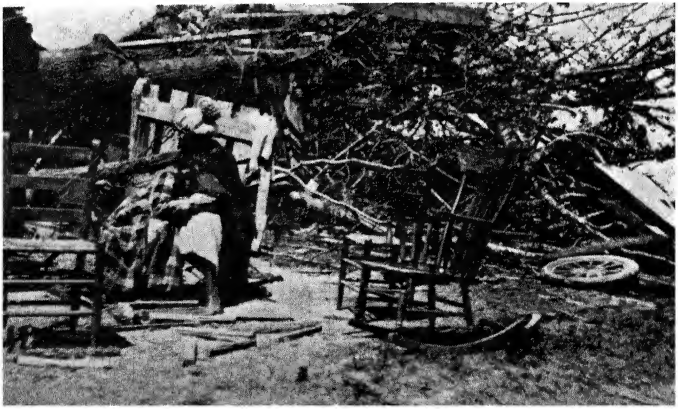


Fig. 27. Remains of a Home near Blevins, Ark. After the tornado of Apr. 15, 1921. *See* pp. 138-140.

water, at the same time whirling it into a mist. As the core of the spout is a partial vacuum, the sea water rises within it, sometimes to a height of eight or ten feet. But the mass of the water above this is fresh, condensed from the atmosphere, as has been demonstrated when a spout has crossed a vessel.

A similar phenomenon on a vastly smaller scale is the "white squall," which is a fair weather whirlwind over the water. In many such instances there is not enough condensation of vapor to form a cloud, though occasionally a small misty cloud, sometimes called a "bull's-eye" is visible. At the surface the wind is strong enough to blow water into white spray, but the whirl is not powerful enough to raise the spray higher than from 20 to 50 feet above the surface.

Hurricane Rainfalls. The weight of water vapor drawn into a West Indian hurricane is prodigious, and the amounts precipitated by the expansional cooling are almost unbelievable. The very centrifugal tendency of the millions of tons of drops of water whirling about the center of the hurricane is thought to be an important cause of the lowness of the atmospheric pressure at the central eye. In fact, the latent heat of condensation of the water vapor that makes the rainfall is the principal source of the energy that drives the

great atmospheric heat engine that is the hurricane.

Perhaps the heaviest rainfall in a single 24-hour period ever measured was 46 inches, at Baguio, the summer capital of the Philippine Islands, July 14-15, 1911. An additional 42 inches fell there during the same storm, making 88 inches in four days. But Silver Hill, Jamaica, had 96.5 inches in four days; and Funkiko, Formosa, had 81.5 inches in three days, July 18-20, 1913. According to data compiled by Dr. S. S. Visher, there were more than 400 days in 25 years on which the rainfall somewhere in tropical Australia exceeded 10 inches. The record in Australia for three days is 63 inches, on Mt. Molloy, Queensland.

These figures exceed records for any part of continental United States, where in a West Indian hurricane our best in one 24-hour period has been 22.22 inches, at Altapass, North Carolina, July 14-15, 1916. The flood which resulted from the rains of this hurricane was the greatest ever known in southern Appalachians.

Hurricane Protracted a Drought. The perversity of weather was well demonstrated in the last week of September, 1923, when a West Indian hurricane seems to have deprived the northeastern United States of a promised rain which was sadly needed to break a long-continued drought, and

at the same time gave to that section of the Great Plains centering in Omaha disastrous floods.

A cyclone, or area of low pressure, had started on its way across the continent from the southwest, when the hurricane swept its way northwestward toward the Florida coast, and swerved northeastward up the Gulf Stream. One result was to accentuate the inflow of cold dry air from the north over the eastern part of the continent, forming an atmospheric dyke which served as a barrier to hold back the approaching "low." Instead of passing onward to bring rain where it was so greatly needed, the resultant precipitation was concentrated in the Omaha region, where an excess of rainfall caused serious floods. In the meantime the reservoirs of the northeastern states continued to get lower, and more and more of the wells and springs dried up, causing discomfort and inconvenience to increase, all apparently because nature selected this particular time and course for a hurricane.

A Trio of Tropical Cyclones. Though the tropical cyclone is best known through the bad reputation of the West Indian hurricane and the typhoon, there are numerous tropical cyclones of much less destructive intensity. Three of these entered the eastern United States and, as two storms, crossed into Canada, October 16-19, 1923.

After a number of days of low pressure in the Gulf of Mexico a tropical cyclone of nearly hurricane intensity was reported by two vessels not far south of Louisiana. The storm reached the coast during the night of October 15-16 and moved northward. Another one arrived early on the 17th. By the evening of the 19th the remains of this pair were somewhere in Canada south of Hudson Bay. These storms readily followed a lane of warm, moist air which during several days before had spread from the Gulf to Canada.

The other storm appearing suddenly from the direction of Bermuda brought rain to New England early on the 18th, before the Weather Bureau could forecast it. The only warning of its approach was the slow rise of high clouds far to the southeast in an otherwise cloudless sky during the 17th, and a northeast wind that did not die at nightfall. A boisterous wind, magnificent festooned clouds, then a heavy shower, and the storm had arrived. Drizzle and rain continued in southern New England with the northeast wind for nearly 24 hours. The weather became muggy as the center approached. Then followed a squally and showery southwest wind for 24 hours more. A tropical storm had passed across New England. It had in moderate form the characteristics of its dreaded relative, the West Indian hurricane.

On account of a restricted supply of moisture it was too weak to make more than about one inch of rain. The Gulf storms operated with air more abundantly supplied with water vapor, and their latent energy was much stronger: the wind rose to 60 miles an hour, and the rainfall totaled nearly 10 inches at Pensacola, Fla.

PART III: AUTUMN

SECTION XIV

AUTUMN FORESHADOWS WINTER

Autumn Frosts. The period of the first destructive frosts of autumn comes early. The extreme northern United States and southern Canada sometimes have them as early as September 1. The arrival of frost is progressively later as latitude is more southerly, but there is no uniformity to the rule. Climatic conditions govern, independent of latitude.

For instance, the average period between the spring and autumn frosts is the same, 180 days, along a line beginning in southeastern Massachusetts, and extending southwestward through Rhode Island, Connecticut, and extreme southern New York; Central New Jersey, southeastern Pennsylvania, and on across the central portions of Maryland and Virginia. Thence the line loops southwestward round the southern Appalachians and the Cumberland plateau, and on northeastward to West Virginia, and from there is not far

from the 39th parallel, until on the Great Plains it trends southwestward to the Texas Panhandle.

Prophecy of local frost is not difficult. If in the early evening the sky is clear, the air still, and the thermometer as low as 40-45° F., there is almost a certainty of frost. If the air is very humid, however, an evening temperature as low as 45° F. need cause no apprehension; and, with a high relative humidity and also a good breeze blowing, even a temperature of 40° F. may not be followed by frost. Should a fog or low clouds form they are likely to prevent loss of much heat from the ground and serve as a protection against frost.

Ordinarily, tender plants can be safely guarded from an early frost by covering them with some poor radiator of heat, such as paper, the purpose being not to keep the cold out, but to keep the heat in by preventing rapid loss of heat from the ground.

Autumn Dews are Heavy. As summer wanes and autumn sets in, and the days get shorter and the nights longer, we have heavy, soaking dews whenever the skies are clear and the air still. Under particularly favorable conditions we may get the equivalent of over 0.01 inch of rain in a single night. Normally in midsummer the formation of dew is moderate, though in some regions, notably

near the coast of southern California, it is uniformly heavy in the warm, dry months and occurs almost nightly, because the sky then is almost invariably clear at night and there is little wind in the hours of darkness. There dew serves to an important extent to replace the rain that rarely falls. The lima beans of Oxnard and the navy beans of San Luis Obispo are practically raised on this dew.

As the nights grow longer, the ground begins earlier to cool by radiation and conduction. The contrasts between day and night temperatures are greater. Dew begins to form as tiny droplets when the ground and objects on it have lost so much of their heat that their surface temperatures fall below the dewpoint of the air in contact with them, that is to say, the temperature at which the moisture of the air condenses as water. Some substances give up their heat by radiation much more rapidly than others. Even between the foliage of different plants there is a wide variation in this respect. Grass, which is kept by evaporation from becoming hot by day, and which has little mass in comparison with its surface, falls to the dewpoint very shortly after the sun ceases to shine on it, in shady spots even some hours before sunset. A dark-colored stone, on the other hand, which has become very warm and

has absorbed so much heat that it requires hours to cool to the dewpoint, may remain perfectly dry throughout the night. The air of an autumn night, however, is often humid, and has much vapor to give up; so this in combination with the considerable cooling causes heavy dews to form on all objects.

The Fogs of Autumn. Autumn brings with it much of what the meteorologists call radiation or lowland fogs, which form in valleys and depressions, especially over rivers, ponds, and lakes. These fogs occur in summer, too; in fact, a common name for them is "summer fog." But they are more frequent and much denser in fall.

In the course of still, warm days much water is evaporated into the lower atmosphere over water surfaces and low-lying land, where in most part it remains as long as there is no wind. This air, because it is humid, and the ground with which it is in contact, both radiate their heat rapidly on a clear, calm night, until finally the air is cooled to a temperature below its dewpoint, making a fog. The surfaces of lakes and rivers steam as if there were fires beneath them. Thus, on many nights hollows and valleys become puddles and ponds of whiteness, which from near-by heights in the light of early morning give the impression of greatly extended sheets of water. Sometimes, however,

the fogs are very limited; and a hollow such as a deep railroad cut will fill with fog, while there is none anywhere else in the immediate vicinity.

Lake Waters Getting Cold. During the summer the surface temperatures of most lakes of the northern United States and southern Canada rise into the 60's and 70's, while in the depths beyond the penetration of summer heat the temperature remains at 39° F., which is the temperature of fresh water at its maximum density. Even by early October, for nearly two months the decreasing heat of the retreating sun and the coolness of the lengthening nights have been favoring the cooling process, which presently will culminate in the formation of ice.

As water at the surface cools it becomes heavier and sinks to a level where the water is equally cold; and this is repeated over and over again, night after night, until eventually the temperature of the lake becomes 39° F. throughout. Thereafter, as the surface water cools it expands, becomes lighter than the water below, and remains at the top. Finally, it cools to 32° F. and ice forms, to become gradually thicker as the winter advances. During the winter the water at the surface next to the ice remains at 32° F., while that at the bottom is 39 degrees. When spring comes the cooling process is reversed.

If a river is deep and slow flowing its temperature behavior is the same as that of a lake, but if the stream is shallow and swift flowing the water will be so mixed as to be of uniform temperature throughout.

Late Autumns on Lake Shores. Though killing frosts occur in early fall over large regions, favored localities, such as those along the shores of the Great Lakes, escape frost till late. This is because the shores of large and deep lakes are decidedly milder in autumn than interior areas. The lake waters and the air over and about them cool very slowly because of the great amount of heat which must be given off to reduce the temperature even a moderate amount.

In the Great Lakes region, the first killing frosts in autumn come much earlier in the northern interior of the lower peninsula of Michigan than on the neighboring shores, the difference being more than 20 days. A large portion of this interior has its first killing frosts on the average before September 21, while along the shore on the east the average date is after October 1, and on the west even after October 11. The occurrence of killing frosts 10 days later on the west side of the northern part of the peninsula than on the east side, is owing to the fact that in the coolest fall weather the winds are generally from the north-

west, so that the west side receives its air somewhat warmed after passage across the lake, while the east side is affected by air cooled over the interior of the peninsula. On account of the tempering influence of Lake Michigan fruit raising is an important industry in the western tier of counties while it is negligible in the eastern tier.

Winter's First Snow, the Snow Squall. The first snow of the season, which usually comes in the northern states and Canada before the autumn has actually merged into winter, is generally the snow squall. Dark clouds race across the sky. The wind is cold and damp and penetrating. A similar condition of the atmosphere in summer would bring mild local thunderstorms. But instead of pelting raindrops we have blustering gusts of snow, usually in big, damp flakes. As the ground still retains some of its warmth, the snow melts as it falls.

Autumn snow squalls may endure for several days. We are in an area of low pressure, as a rule in a "trough" of low pressure, with "highs" both to the north and south, a condition which may not end quickly. A southwest wind has been blowing, bringing moist warm air from the Gulf Stream, and a west or northwest wind is bringing in cold air a half a mile or a mile aloft. As cold air descends here and there it violently lifts masses of

warm air, the moisture of which condenses and crystallizes as snow. It falls in squalls, which may occur several times in an afternoon.

In 1923 the first snow flurries in Maine were reported on October 1st, caused by convection and the crowding of cool winds on the margin of a West Indian hurricane.

Beginning of Pacific Rainy Season. The rainy season of the Pacific coast is usually well under way by the end of November. Storms are increasing, especially in the north; in southern Alaska, British Columbia, Washington, Oregon, and northern California, there are stronger winds onshore, warm and moist from the southwest. They are meeting the high mountains and masses of cold air, great obstructions over which they ride, chilling by expansion as they ascend, to condense their moisture as rain or snow. In the autumn this results in rain near sea-level but snow on the mountains. As the season progresses the storms become larger and reach farther south, bringing the beginning of the rainy season later and later southward. Normal autumn rainfall ranges from over 30 inches at Sitka to 20 inches in northern California. The rainfall of September and October, 1923, on the north Pacific coast of the United States was slightly below normal.

In this connection it is interesting and impor-

tant to note that Dr. G. F. McEwen, oceanographer of the Scripps Institution for Biological Research at La Jolla, California, expected only two-thirds of the normal rainfall in southern California the winter of 1923-24, because previous experience had shown that dry seasons follow late summer and early autumn ocean temperatures above the normal. The Pacific at La Jolla was warmer in this period of 1923 than in any of the preceding seven years. The actual rainfall was about half the normal—the least since Dr. McEwen began his water temperature observations.

SECTION XV

AUTUMN WINDS AND STORMS

Travels of Smoke. When smoke is produced in great quantities it usually travels far before it ceases to be recognizable. It is well known that the bigger the smoke the farther it may go. Many times during the year the smoke of the Pittsburgh region may be seen arriving in Washington, D. C., borne by northwesterly winds. Even the smoke from the region about New York City is easily discernible after it has traveled 30 or more miles. In eastern Massachusetts a smoke pall from the industrial cities of southern New England at least 50 miles away often reduces the visibility.

But these travels of city smoke are dwarfed by the hundreds and even thousands of miles that forest fire smoke traverses. The smoke from the great forest fires in Idaho in August, 1910, was so dense when it reached Minnesota, a thousand miles away, that the sun was obscured by it for a week, and it was too dark at noon even to read newsprint on an open beach. In Minneapolis the visibility was reduced to less than a quarter of a mile. This smoke spread east to the Atlantic

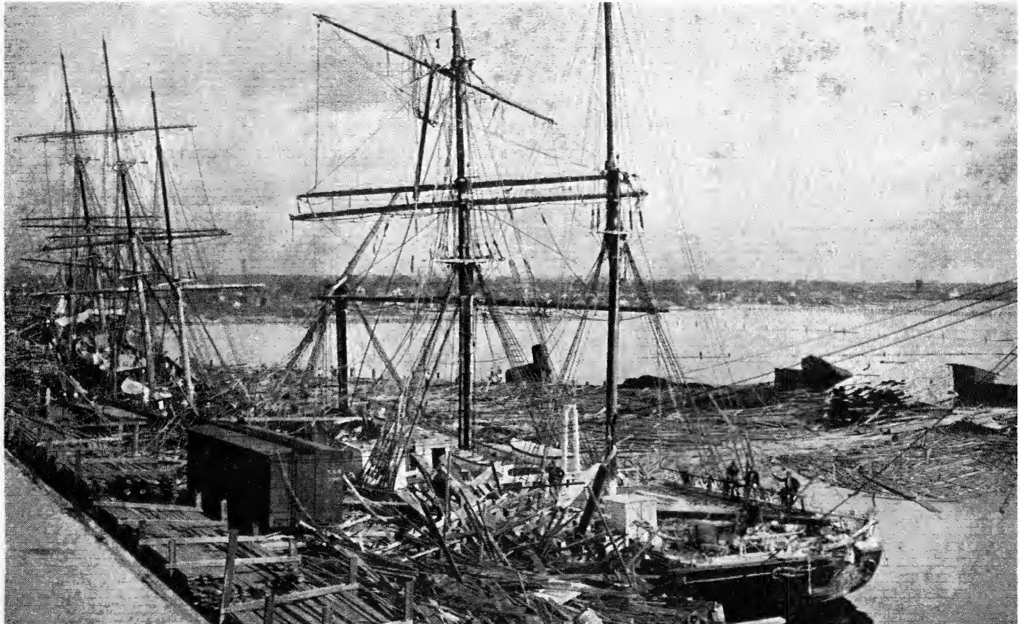
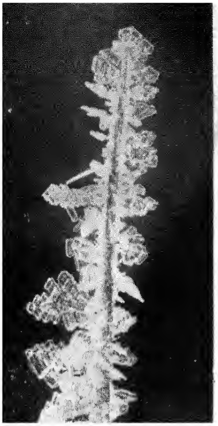


Fig. 28. A Portion of the Gulf Coast After a Hurricane Had Passed
See pp. 158-159.



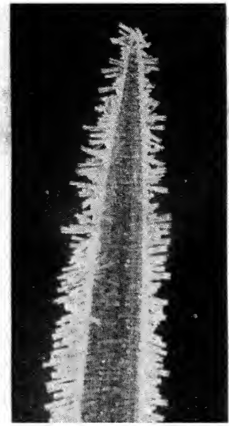


Fig. 29. Tabular hoar frost on tree twig (winter frost).

Fig. 30. Columnar hoar frost on grass blade.

Fig. 31. Tabular hoar frost on pigweed.

Fig. 32. Columnar hoar frost on strawberry leaf.

Tabular and Spicular Frost Crystals. Such crystals form, as do snow flakes, when condensation occurs at temperatures below freezing. (Photos by W. A. Bentley, Jericho, Vt.) *See* pp. 169-170.

seaboard. In October, 1918, the smoke from the great forest fire near Duluth, Minnesota, spread with a front so definite that its hour of arrival was reported at station after station to the Atlantic coast and the Gulf states. Starting with strong west and northwest winds from Duluth on the evening of October 12, dense smoke reached Indianapolis by the next morning, and a line from Washington, D. C., to western New England by the evening of the 13th. It covered 1000 miles in 24 hours. The spread was slower southward with weaker winds, the smoke not being reported in Georgia and South Carolina till the 14th, nor in Texas till the morning of the 15th. The smell of the smoke was very evident in Texas, more than 1100 miles from the source.

Early Autumn Storms. The storms of early autumn give us a boisterous foretaste of winter. As the general atmospheric circulation gains speed, so the storms, which mark the irregularities in the boundaries between the equatorial and polar winds, move faster. And they become stronger than the summer storms, developed as the latter are from weaker winds.

The contrast in 1923, however, was not so marked as usual with the transition from summer into autumn; for throughout the summer the coldness of the north and northeast maintained

unsummer-like, strong winds and rapidly moving storms. Many of our autumn storms are even weaker or moving more slowly than a number of these summer ones. As with the summer "lows," the more slowly moving storms bring the largest changes of the weather and the heaviest precipitation, while the more rapidly passing ones do not involve enough air for a sufficient time to make great changes or much rainfall.

Northeasters Come From Southwest. Benjamin Franklin who, with his many other accomplishments, was an excellent meteorologist, determined to observe an approaching eclipse of the moon, and induced his brother to do likewise. Franklin was in Philadelphia, his brother in Boston. A northeast storm came up the coast and the weather was stormy in Philadelphia. But the Boston observer had a clear view of the eclipse, and wrote to Franklin about it and mentioned that the sky had clouded over and a northeast storm had begun after the eclipse.

Franklin noted what may have seemed to him an anomaly: the northeaster always arrives from the southwest, "comes up the coast," as the saying goes. Storm signals are always displayed between Savannah and Hatteras earlier than between Hatteras and the Delaware Capes. While the storm is in progress the wind blows from the

northeast, but it always begins to blow from that direction first in the south. The reason is that winds flow spirally inward towards and not away from the centers of storms. A storm over eastern Virginia causes northeast winds in Philadelphia. As it travels northwards the area of northeast winds also travels northwards.

Storms That Go Astray. A bane of the weather forecaster's existence is the storm which goes astray. Normally weather travels in beaten tracks across the American continent, and the forecaster, knowing from his map that a storm center, is, say, over Cincinnati, and knowing its direction and speed of travel, may confidently expect it to reach Philadelphia or New York at about the same hour on the following day. He may predict fair weather with mild southerly winds for Baltimore and Washington and rain or snow with chilly easterly winds for New York state and New England.

But every once in a while, as when cold air and high pressure appear in New England, such a storm will veer off, and perhaps take a dip southward and pass out to sea near Cape May, and when it does so the previous forecasts made for the Atlantic states north of Cape Hatteras are upset. Northern New York and New England have beautiful, cold, fair weather, while Baltimore

and Washington have cloudiness and rain instead of the predicted sunshine.

A cyclonic storm may not only swerve from its predicted track, but it may also fail to produce rain or snow, without which to the popular mind it is not a storm at all.

October Snows in the East. In the autumn of 1923 the first snows in the East came, paradoxically, as a result of tropical cyclones or storms that grew out of them, for these were the only storms with sufficient intensity on their cold side to draw down air from the far north and cause precipitation at a temperature low enough for snow. There were three types of snows October, 1923, that well illustrate the usual October snowfalls in the regions where they occurred.

Flurries were reported in Maine on October 1, and in Massachusetts on the 18th, but such light snows along the coast cannot equal those of a previous October when the feathery flakes fell as far south as southeastern Virginia and eastern North Carolina.

The second type of snowfall, that of heavy snow on the leeward shores of the Great Lakes, was typified by the reported fall of two feet in the region north of Lake Huron which blocked the trains in that region on October 20, 1923. While the average October snowfall in the parts of the

Lake region where moisture-laden air from the Lakes may be forced upwards with large masses of cold air and condensed, is only from one to three inches, these averages are usually the result of the rare heavy falls that contribute a foot or two at a time.

Finally, the mountain type of snowfall was represented in the fall of a foot or less reported October 24, 1923, in the mountain and highland region where Tennessee, Virginia, and North Carolina meet. Only in the lee of the Great Lakes and on the highlands of northern New England and New York and regions northward do average October snowfalls equal those of the southern Appalachians, favored as these are by exposure to the strong winds of coastal cyclones.

Autumn Gales on the Great Lakes. In November, when the lands surrounding the Great Lakes get their first snowfall and the Lake waters are still relatively warm, the temperature contrasts which are produced tend actively to attract and intensify the passing storms. When the air to the northward is abnormally cold, as the wind sweeps down from that quarter, a storm may assume a menacing severity, with a heavy gale, extreme cold and snow, the worst kind of a combination for the seaman. Lake shipping suffers.

Storms of the great inland seas are more disas-

trous than those of the open ocean, because there is less space for drifting and because of powerful lake currents during gales which take the ship out of control. Also, the fresh lake water is lighter than the salt water of the ocean and is therefore more easily heaped up into great waves by a strong wind. When the December gales arrive and also the snowstorms which continue till spring, shipping remains safe in port, because ice closes the lakes to navigation.

Windshift Line is Stormy. The windshift line plays an important part in the weather. It may be defined as the line of contact where cold wind strikes a warm wind, the line usually advancing across the country in an easterly direction. Often a hot, moist wind blows from the Gulf or the Atlantic, sending up the mercury and bringing extreme humidity, while the barometer is low. Then an area of high pressure approaches from the west, accompanied by a cold wind. The cold air locally overrides the warm, which then rises; or it enters as a wedge under the warm air and forces it upward, in either case making it cool suddenly, mostly by expanding as it rises. Rain forms, accompanied sometimes by severe electrical disturbances. Or, the contrasting temperatures of the meeting winds may not be so great as to cause more than ordinary rain.

It is not difficult to visualize this line of contact, perhaps several hundred miles long, extending in a north and south direction, as it passes, perhaps rapidly, perhaps more deliberately, across the continent. As the line passes out to sea and the cold wind strikes the warm, humid air over the Gulf Stream, waterspouts are often formed.

Cold Weather Thunderstorms. By November 1 the season of local thunderstorms is past, but thunderstorms occur in cold weather as well as in warm, and, while not so severe, are fully as dangerous, because the thunderclouds hang low in winter and lightning strikes easily.

Most of the cold weather thunderstorms occur in the darkness, for the contrast between the warm and cold air is greatest at night. The thunderstorm zone may be several hundred miles in length as it sweeps eastward across the country, and therefore the thunderstorms may cover a vast expanse of territory.

The Ice Storm. The ice storm, known in England as glazed frost, is not an uncommon phenomenon in the United States, though, fortunately, rarely occurring in its most severe form, when overwhelming accumulations of ice, in combination with a gale of wind, bring great devastation to the trees and to telegraph, telephone and other exposed electrical transmission lines. Nor is the ice

storm confined to the northern states, for it is by no means unknown in the south, though not often as a destructive element of weather.

The combination of temperatures and humidity which result in the ice storm occurs more often than is realized by the superficial observer. New England, where the phenomenon most frequently occurs, has a number of them each winter. The first (1923-1924) occurred October 23 in western Massachusetts at heights above 2200 feet. Once in a great while conditions arise which are especially favorable, such as were experienced in southern central New England and New York November 26-29, 1921. A three-day ice storm occurred, doing millions of dollars' damage. A similar storm occurred late the following February in central Michigan when electric wires carried two pounds or more of ice to the foot, and the lighthouse at Frankfurt had an ice coating an inch and three-quarters thick.

No other aspect of the northern winter is so beautiful as the ice storm, particularly in the sunshine following, when all nature seems encrusted with glittering diamonds.

Cause of the Ice Storm. The ice storm occurs usually when it is cold at the earth's surface, with rain falling from warm, moist air aloft. The ideal condition for a dangerous storm is when the

ground has been cooled to below the freezing point and the air above it is also well below 32° F., while the higher levels are warm.

This combination may arise in any one of three ways; one where warm, moist air arrives over a layer of residual cool air at the ground; another by cold air coming in below from the north, while a warm current from the south arrives above; and the third, when arriving cold air from the north or west pushes in under a raincloud.

In any case, the mass of cold air in the path of the warm wind causes the latter to rise, and in so doing to cool by expansion to such a degree that much of its moisture is precipitated as rain. The raindrops freeze quickly when they strike a cold object. Consequently, drops coming in contact with vegetation or other surfaces which are below the freezing point, are quickly converted into ice. Continuing rainfall constantly increases the accumulations, sometimes to a great thickness.

The Great New England Ice Storm. The New England ice storm of November 26-29, 1921, may be accepted as an extreme form of this phenomenon. Following days of clear, cold weather, snow set in on a Saturday afternoon and soon changed to rain, which, falling through cold air and onto surfaces below freezing, began to form as ice. Sunday it rained and sleeted alternately or to-

gether, while the thermometer fell to 25° F. At night it began to rain steadily and ice as steadily to form. Morning saw an inch-thick armor of ice over everything out-of-doors, and still it rained and froze, while the northeast wind increased to a gale. By afternoon city streets were dangerous. Everywhere branches and trees and electric wires and poles were falling.

A wild and terrible night followed. Electric lights were extinguished, and cities and towns lay in blackness. Trolley cars ceased running, telegraph and telephone service was gone, streets were impassable to vehicles, some of them to pedestrians. The climax was a thunderstorm with pink lightning flashes, the thunder crashing to an accompaniment of falling trees.

Ice was two inches thick on the wires. It was estimated that a tree 50 feet high with an average width of 20 feet carried a load of five tons of ice. Few trees could bear the burden. The plumed elms were ruins, whole orchards were destroyed, long lines of telephone poles fell, in some cases a mile at a stretch. Forest trees lay prostrate in windrows. The money damage went into millions of dollars.

Cold Weather Winds are Strongest. The windiest zone of the northern hemisphere embraces the northern United States and southern Canada. The windiest months are those of late autumn,

winter, and very early spring. August has the lowest average wind velocity, March and early April the highest.

Wind is the flow of air from an area of high air pressure slantwise to an area of low pressure. The greater the contrast of pressure between the masses of air over two adjacent regions, the swifter and stronger will the wind blow. Pressure differences are largely dependent upon temperature contrasts. In summer the temperature contrast between high and low latitudes is relatively small, in winter it is great, for while the snow and ice-covered north gets colder and colder, in low latitudes there is little temperature variation through the year. Therefore, the pressure gradient, to use the term of meteorology, is gentle in summer and steep in winter. The gradient may be likened to a slope of land. The air pushes down the gradient, from high pressure to low, as water flows down a variable slope, the steeper the slope, the greater the velocity, whether it be air or water. Therefore, because the gradient is steeper in the cold months the fiercer are the winds. There is, however, a curious difference between the flow of a stream of water and that of the air. The water flows down the slope, the air along it, owing to the rotation of the earth on its axis.

SECTION XVI

WEATHER PERIODS AND MAJOR AIR STREAMS

The Weather's Habit. Weather very often repeats itself. A rainy day, or week, or month, or year, for example, is more apt than not to be followed by another rainy day, week, month, or year. The same is true of a dry or hot or cold period of weather. For example, at Brussels, Belgium, the probability of a change the next day to fair weather after seven days with rain is only 25 per cent, and of a change in temperature after 7 warm or cold days only 15 per cent.

To produce any kind of weather we have a certain combination of conditions, such as surface temperature, air temperature, and moisture, and therefore such weather as results will tend to repeat itself so long as the fundamental situation remains unchanged. It is more remarkable, perhaps, that our weather changes as often as it does, than that it tends to stay the same for longer or shorter periods.

In any portion of the earth the amount of solar heat received, called insolation, changes but gradually with the progress of the seasons. The result-

ing general temperatures of the continents and oceans, in consequence, change but slowly, even more slowly than does the insolation, especially in the case of the ocean surface and deeply snow-covered ground. If the general conditions favor the formation of a storm or an accumulation of cold air in a certain region and its travel thence to another region, a series of storms or cold waves may follow the first, giving much the same round of weather, time and again, for from two to eight weeks. Therefore, the weather may be said to acquire habits.

A Warm Autumn in Alaska. The warmth of the fall of 1923 in Alaska which allowed the Yukon to remain open and gold dredging operations to continue to the end of October was looked upon with interest by American forecasters. This is the time of year when heavy masses of cold air begin to accumulate in the Arctic and to drain southward in ever-increasing quantity. The cold outflows that affect the middle latitudes of North America often come out of Alaska and Yukon Territory. Unusually cold air and high pressures are reported there a week or more before an Alaskan cold wave reaches Saskatchewan and North Dakota. In the autumn of 1917, prior to the extraordinarily cold winter of 1917-1918 in eastern North America, Alaska early showed the

formation of the great masses of cold air which, after a number of preliminary cold waves, broke forth in tremendous volume and engulfed millions of square miles to the southeast in their frigidity.

Such early accumulations, there, were lacking this autumn much as they were a year before. The winter 1922-23 was mild in the Middle West till February; but we were not to conclude that the next winter would be likewise. The cold wave and heavy snowfall in the West, blocking traffic over a large area, near the end of October, 1923, was enough to show that we could be cold without importing the coldness all the way from the Yukon basin. The great mass of cold air that brought such unseasonably cold weather and early heavy snows in the Rockies and adjacent plateaus and plains came from the north Pacific by way of the Canadian Northwest.

Volcanic Eruptions Produce Cold. After a tremendous volcanic explosion occurs, throwing fine ash to a height of nine or ten miles, the earth may experience a season or more of unusual cold. The minute particles of ash in the upper atmosphere may be carried all over the world. Those above the general level reached by convection will not be brought down by rain or descending air currents; friction will serve to keep them from settling or falling, save very slowly.

A veil of volcanic dust in the upper air reflects, absorbs, and radiates into space some of the heat from the sun which would otherwise reach the earth's surface. The tremendous eruption of Tomboro in the East Indies in 1816 was followed by an extraordinarily cool summer; indeed 1816 became known afterwards as the "year without a summer." Snow fell in June, July, and August, in various parts of New England. Similarly, in 1883, after the severe explosion of Krakatoa, another East Indian volcano, the world experienced unusual cold. Moreover, the coolness in the last half of 1912 was evidently intensified by dust from Katmai volcano, Alaska. Another result of the volcanic ash aloft is the production of remarkably brilliant red sunsets and sunrises. As the rays pass obliquely through the very dusty upper air, the shorter wave lengths of light are interfered with more than usual, leaving a preponderance of reds in the light which reaches the surface. In 1912, the eruption of Katmai produced a series of magnificent sunsets, similar to those noted after the explosion of Krakatoa. Dr. W. J. Humphreys of the Weather Bureau has stated that the 1923 eruption of Mt. Etna was not sufficiently explosive in character to carry volcanic dust far enough aloft to affect our weather materially.

Great Exchange of Air With Tropics. During the latter part of October, 1923, there was an enormous flow of cool, dense air from the western and northern part of our continent to the Gulf of Mexico and Caribbean Sea. The accumulation of this air over the cooler western plateau of the United States and over northern and northeastern Canada seems to have taken place largely during the middle of October when the interior of the continent became warm and humid and the weight of air over it much less than usual. Toward and around the west side of this large low-pressure area came this flow of colder, heavier air.

The cold air spread southwards and southeastwards, attended by frosts even into the Gulf States, until by the 22nd it covered the eastern United States, and was flowing in great volume thence into the tropics. On the east and on the west there was a counterflow of air displaced from the tropics by this broad and deep wedge of cool air and another somewhat similar one farther east, heading southwards from the Canadian Maritime Provinces.

These counterflows carrying large volumes of moisture from the tropics and crowding into and over the cold tongues of air resulted in rainfall in the West and heavy rains on the eastern seaboard.

Over the Gulf Stream a major storm center of great intensity developed, and whirled north-northwestward along the middle Atlantic coast.

Northers and Where They Go. The Norther of the Great Plains is one of the most far-reaching features of American weather. When it extends its path into the sub-tropical sections of the United States it may prove highly destructive to the citrus fruit trees. It is caused by the piling up of vast masses of air usually in the regions north of Alberta, even as far as Alaska and beyond in Siberia. Finally this accumulated icy air overflows southward in a tremendous sweep, especially when drawn, as it were, by an area of low air pressure over Texas or the Gulf of Mexico. It rushes down over the Great Plains, carrying with it very low temperatures. Often it arrives with little or no warning, and the mercury may drop 40 and even 50 degrees in a few hours.

The piled up air of the north maintains the Norther's advance, pushing it from behind until the cold wave may extend down to the Gulf States, and even across the Gulf and the Isthmus of Panama within the tropics, bringing with it a dreaded condition of chilliness and torrential rains. Serious disturbances may follow in the Pacific, south of the Isthmus, which may breed a hurricane.

Similarly, the norther of the eastern states may

be pushed far south, to embrace almost the whole of Florida, with the exception of the extreme southern keys, which is the only spot in the United States that has never been nipped by killing frost. Cool weather may even pass on into the West Indies, there to be marked by much cloudiness and showers.

Flood Rains in Mexico and Panama. During September, October and November, 1923, rains of "unprecedented" volume fell more or less continuously for days and days during the prevalence of the unusual gales of cold air from North America into the tropics. Innumerable washouts and landslides over much of the country rendered railroad travel dangerous and almost impossible.

Similar conditions probably prevailed throughout Central America, for great floods occurred in Panama, especially during the latter part of October. Autumn rains in Panama are always heavy, as at this season large masses of very humid air are being forced upward by the invading colder air from the north. October normally gives Panama from 10 to 17 inches of rain, but the great rainfall experienced in 1923 far surpassed these amounts. Totals for October, 1923, ranged from 12.69 to 44.35 inches. The rainfall for the month at Colon was about 42 inches, and at Gatun, 40, of which over 35 inches fell in the seven days, Octo-

ber 21-27. Panama in such wet times receives in one month about as much rain as the average for the United States for a year.

How hard it can rain in Panama is shown in the records of Porto Bello on the Atlantic Coast of the Canal Zone. Forty-eight inches is the average rainfall there in October and November together. Rains of five inches or more in a day are not infrequent, while on November 29, 1911, 6.31 inches was recorded in two hours, and 2.47 inches of this amount in only three minutes.

SECTION XVII

AUTUMN WEATHER PROVERBS

When Geese Fly South. Do not place too much confidence in an early flight of wild geese south as indicating an early winter. It is true that the premature arrival of extreme cold in the far north, by freezing over inland waters, may start the flocks early, and such an abnormal condition has weather significance, for early cold in the far north is felt here later.

But more often, probably, the flight of the geese begins before the feeding places of their summer home country are sealed with ice. Food supply may diminish, or there may be an overpopulation resulting from the season's yield of young birds. Then, too, in some seasons the geese are able to nest earlier, and the goslings reach the adult age sooner. Seldom do the flocks start away from the breeding places until the young birds are strong enough to keep up with their parents. The Canada goose is well known for its solicitous care of its offspring.

In the early fall geese are seen flying north as well as south, as they move hither and thither in

search of food on their leisurely journey to their winter homes. Not until the weather becomes very cold does the final, general flight take place.

Fur and Feather Fallacies. Every fall the word goes about that the wild animals and birds have extraordinarily thick fur or feathers, a "certain sign" that the winter will be early and severe, "one of the worst in years"; or else that beast and fowl have but meager winter coats and therefore the winter will be an open one. Almost always the prophecy is prefaced by "They say." The old time hunter who chances to shoot a full-feathered grouse or quail sends forth the cry of terrible cold ahead, while as likely as not on the same day another old hunter will kill some creature less sumptuously clad and declare that a "green Christmas" may be expected.

Such portents as an indication of forecasting ability in animals have been wholly discredited by scientific investigation and by the observations of intelligent people generally. Neither animals nor birds possess an instinct which foretells the weather of a season yet to come. It is the food supply and other conditions of the season past and present which determine the quality of their winter overcoats, and not the season which is to come. Only in so far as a cold winter may follow a cool fall, or a mild winter a warm autumn can

features dependent on existing conditions give any indication of the future weather. Since there is a small tendency for a cool season to be followed by one of like character, the fur and feather indications are not always wholly fallacious.

Indian Summer. The autumn that does not have, either late in October or in November at least one period of the warm weather that we know as Indian Summer, is rare enough. Sometimes there are two distinct series of these days, separated by a colder spell; more rarely there are three; one is practically certain. In the midst of early cold days, when there has been heavy frost at night and ice has formed of mornings, and there has been bleak and stormy weather, there comes as a reprieve from winter, a brief but glorious interlude of warmth and balminess. The landscapes are golden, set in an atmosphere of wonderful blue haze. It seems, indeed, that summer has come again, though on an autumn plane of temperature.

Indian Summer arrives in the transition period, as summer merges into winter, and quite naturally the weather may assume alternately the characteristics of either in a modified degree. The atmosphere is subject to less violent agitation in the late fall than in the spring, when the air is in strong circulation between the heated south and

the snow-covered north. There is less of turbulence generally and fewer local storms. Areas of high and low pressure pass less swiftly, and therefore when Indian Summer comes with some stagnant or slowly moving "high" centered in the South it usually remains for a number of days.

The Naming of Indian Summer. How the periods of warm, calm weather which arrive almost invariably in late October or in November came to be known as Indian Summer has been variously explained. The most commonly accepted explanation is that the American Indians recognized it as a season certain to come at least once, and in some years more than once, and depended upon it as a time for final preparations for winter, in the storing of their late crops, whatever these were, and in making ready their winter lodges.

Another version is that the early settlers attributed the blue haze which is characteristic of the season to the smoke of fires set by the Indians on the western prairies, and bestowed the name for that reason. Yet another suggested possibility is that the name was bestowed by some early traveler, who, familiar with the dry, hazy weather of India, recognized a similar kind of weather here. The term "Indian Summer" has been applied for some time by British mariners to the

fine weather of the cool season on the Indian Ocean.

Autumn Haze. The beautiful blue haze of autumn is due chiefly to the presence of smoke in the atmosphere, or rather to the dust particles originating in smoke. In the fall of the year, when the ground is carpeted with dried grass and dead leaves, fires are all too frequent. Their smoke hangs low and travels far, because there is very little formation of vertical air currents which would serve to dissipate it. An atmosphere laden with smoke dust always looks blue when seen away from the sun, and the result is one of the most beautiful phenomena of nature, the haze which we usually associate with Indian Summer.

Every autumn some parts of the country suffer from drought and become tinder-dry, and the carelessness of man does the rest. An abandoned campfire, the thoughtless dropping of a lighted match or live coal from a pipe or a burning cigarette, or a spark from a locomotive stack, any one of these may start a fire which, if conditions favor, will cover thousands of square miles with smoke-dust as it drifts hundreds of miles across the land. If there be any compensation whatever for a vast waste of natural resources, it is the beauty of the blue haze of autumn, and its harmony with the gay-colored landscape.

"When the Peacock Loudly Bawls." Sometimes when the air is extraordinarily clear and distant objects are visible with unusual sharpness and sounds come from afar with startling distinctness, it is a warning of foul weather. Then it is,

> When the peacock loudly bawls
> Soon we'll have both rain and squalls.

Under these atmospheric conditions the songs and cries of birds sound loud to the ear. The barking of dogs, the lowing of cattle, the whistles of locomotives, the honking of motor horns, come from far away, whence sounds are not commonly heard. To the eye the difference of visibility from the ordinary may be likened to the contrast between a view through a pane of ordinary window glass and that through one of plate glass.

The reason is that early during the occurrence of a warmer southerly wind at a moderate height, a condition usually preceding a storm, a stratus cloud is likely to cut off the sun's heating from the ground and so prevent irregularities in heating and also permit the surface air to remain cool. The result is a homogeneous lower atmosphere through which light and sound waves travel without local disturbance. The sound waves are further intensified at a distance from their source

by a phenomenon common on a quiet morning after a clear night when the air close to the surface is cooler than that a few hundred feet aloft. There is a concentration of the waves. In the warmer air at a moderate height the sound waves travel faster than in the lower colder air, so those that ascend are bent back to earth and combine with those that travel the normal straight course, thus intensifying the sound in the listener's ears.

Moon's Ring Heralds Storms. The ring around the moon or sun is really a portent of stormy weather, winter or summer. The Zuni Indians were scientifically correct when they framed the adage:

> When the sun is in his house it will rain soon.

The big, colorless, or nearly colorless, ring is due to refraction by ice crystals of the lofty cirrus clouds, the coming of which indicates the approach of a storm. They fly much faster than the rain or snow-producing body of the storm and appear as the vanguard. The first arrivals are the thinnest and loftiest, and therefore the ring is seen, sharp, perhaps, and being farther away than it seems appears to be small. With the nearer approach of the storm the ring, fainter and wider, is seen in denser, lower clouds and seems larger

because it is closer than it appears to be. Hence, to quote an ancient saying:

> The bigger the ring, the nearer the wet.

The Corona. The rainbow-hued corona as well as the halo, or "ring around the moon," is sometimes a concurrent forecaster of a coming storm. Its colored rings hug tight the sun or moon, the inside ring a whitish blue, the outer of the series red. It is more often observed in connection with the moon; for, although it occurs fully as often encircling the sun it is noticed less frequently because of the difficulty in gazing upon the brighter orb.

The corona is caused by the diffraction of light as it passes through the spaces between water droplets. The smaller the drops the larger is the ring, the larger the drops the smaller the ring. When a corona is observed to be rapidly becoming smaller it may, in conjunction with other signs, be taken as an indication that a storm is imminent, because the more humid the air the larger the droplets, and when this change takes place quickly foul weather usually is approaching. The halo, the large ring around the moon or sun, is caused by the presence of a thin sheet of ice crystals high in the air, which occurs more com-

monly than a continuous thin sheet of water droplets in advance of a storm, for which reason the halo is more often to be seen before a storm. Occasionally both halo and corona are visible at the same time, presumably on separate cloud layers.

When Stars Begin to Huddle. When the big stars seem larger and shine faintly with a milky light, and the little stars have disappeared from sight, watch out for foul weather. The adage has it:

> When the stars begin to huddle,
> The earth will soon become a puddle.

Only the great mother stars remain, so to speak. The less conspicuous stars seem to have huddled about the brighter ones, just as little chickens huddle under the wings and fluffed-up feathers of the mother hen.

The reason is much the same as that which causes the ring around the moon, the presence high aloft of a cirro-stratus cloud of falling snow, flung by its greater speed far in advance of an approaching storm mass. Presently even the larger stars are obscured; for the lofty, racing clouds become less tenuous as the snow falls to lower levels with the nearer approach of the storm.

Rain Before Seven, Shine Before Eleven. There is much truth in the weather saying, "Rain before seven, shine before eleven." In a large proportion of the cases where rain falls in the night and early morning, the weather clears in the forenoon and the sun "shines before eleven." The chief exceptions are in stormy conditions, as with northeast winds or boisterous southerly ones.

Rains usually last only a few hours, therefore, those which start before seven are likely to stop before eleven. This is especially probable, however, with those rains that do not start till the cooler hours of the night, for in most such cases the clouds and rain would not have occurred except for this nocturnal cooling. This being so, the morning warming must stop the rain and evaporate the clouds.

Sometimes, however, the rains "before seven" are the result of strong reactions between over and underrunning winds of extensive storms. Such, for example, is the case when the surface wind is from the northeast, providing a cool wedge over which a warmer southerly wind is rising and cooling. And such is the situation when, with a strong south wind, heavy rain is falling. So the "Rain before seven, shine before eleven" applies to our quiet, moderate to light rains but not to

the storm rains over which nocturnal cooling and diurnal heating have little control.

Threatening Mornings. A certain type of morning is sure to mislead many owners of umbrellas. The day looks dark, to be sure, a low sheet cloud covers the sky, but no rain is falling. A column of smoke from a chimney rises straight, it is calm aloft. Typically, under these conditions the night was clear. A warm, moist layer aloft became cooled by radiation or by mixture with the ground-chilled air below, condensation occurred, and a thick cloud formed. If such a cloud is going to produce rain, it is likely to do so while the nocturnal cooling is in progress. When morning comes, the sun shining through the clear, upper air will soon dissipate this low, sheet cloud, which was not a storm indication at all, but hardly more than a sort of high fog.

SECTION XVIII

OUR ATMOSPHERE

Properties of Air. The air we live in is a mixture of gases and has the usual properties of a gas. To consider a few of its characteristics: It is mobile and flows freely and sometimes very rapidly, producing winds of tremendous power. It has low density and is capable of unlimited expansion. It is highly compressible and elastic, forming a good medium for the transmission of sound waves. Imagine the impossible, a person living in a vacuum, with no air to transmit sound waves. To hear an approaching train he would have to put his head against the rail of the track! Air is a very poor conductor of heat, its conductivity is only 1-20,000 that of copper. On this depends largely the blanketing effect of a snow cover, as snow contains so much air. Yet air conducts heat much better than nothing at all, for to make a thermos bottle we remove nearly all the air between the two containers, producing almost a vacuum.

Air has a specific heat of 0.24 at constant pressure, or about a quarter that of water. But it

would take only about 1-3300 as much heat to warm a given volume of air one degree as to warm the same volume of water one degree. In spite of this, the lower air is not very much warmed by the passage of the sunlight through it, as it does not absorb radiant heat readily. It is warmed rather from contact with the warm earth.

The Gases We Live In. The Greek philosophers thought of the atmosphere as one of the four elements. We now know, however, that air is not an element, but a mixture of gases. Each gas exists practically as if none of the others was present. Thus the heavier gases form a larger proportion of the lower atmosphere than they do of the higher. For example, helium, a very light, non-explosive gas, now extracted from a natural gas for use in balloons, constitutes only .004 per cent by volume of the air at sea level, but may form a much larger part of the upper atmosphere. At sea level, perfectly dry air would contain about 78 per cent by volume of nitrogen, 21 per cent of hydrogen, and minute quantities of several other gases.

Nitrogen, an inert gas amounting to a little over three-fourths of the volume of the air, gives body to the atmosphere and dilutes the oxygen. The compounds of nitrogen made by bacterial action, electrical discharges, and various chemical

processes supply essential food to plants and animals and give us the basis for explosives and many other chemical products. Oxygen, unlike nitrogen, combines readily with carbon, and is the basis of combustion. The carbon dioxide content of the atmosphere is quite variable, as carbon dioxide is taken up by plants and given off by animals. Air in closed rooms may contain as much as one per cent of CO_2, which with water vapor and dust, acts as a heat regulator in the atmosphere.

The water vapor present in the atmosphere displaces air equal to itself in volume. Although small in amount, never exceeding 4 per cent by volume of the atmosphere, it is the source of clouds and rainfall. It is lighter than air, so that moist air, instead of being "heavy," is actually lighter than air at the same temperature and pressure.

Dust in the Air. The atmosphere, particularly near the surface of the earth, contains vast numbers of small particles. Such particles may be organic, including bacteria and the spores of plants, often of microscopic size. Over mountains and oceans there is at least one such particle to every cubic centimeter; in crowded houses the number may run up to 80,000 in the same space. But still more numerous are the inorganic particles usually spoken of as dust, though including mere nuclei

on which condensation takes place. Indoors they are often plentiful and large enough to be plainly seen in a beam of light. One set of observations gives the comparative numbers per cubic centimeter under various conditions:

Outdoors, raining,		32,000	per	c.c.
"	fair,	130,000	"	"
In a room,		1,860,000	"	"

The great majority of these, however, are invisible, even under a powerful microscope. One puff of cigarette smoke may contain as many as four billion particles.

Dust comes from innumerable sources, from the ground, from volcanoes, smoke, the evaporation of ocean spray, meteorites, plants, and animals.

Lest we regret too much the necessity of living in a dusty atmosphere, it is well to remember that only excessive dust is injurious, and that dust has its important functions. Dust particles act as centers of condensation for moisture, reflect and scatter light, and they absorb heat and decrease the loss of heat from the earth.

Sun Seen Below Horizon. Refraction is the cause of strange atmospheric phenomena. The mirage, "towering" or looming which makes objects far or near seem unnaturally tall, or which enables the human eye actually to see objects

which normally are out of sight below the horizon or behind some other object, and various other similar effects, occur when light rays are refracted, which means they are bent, for example, as an oar pushed beneath the water's surface seems to bend sharply. When light rays pass through a homogeneous atmosphere they come almost straight to the eye. But sometimes conditions are created in the air which causes light rays to bend materially. In nature there is always a certain amount of this refraction, but usually it does not affect vision in a marked degree.

Normal ray-bending is such that at dawn the eye actually sees the sun while its entire orb is below the horizon. Similarly, at evening after the sun has dropped completely below the horizon it is still fully visible. The reason is that the greater density of the layers of air next the earth as compared with those above causes the sun's rays to pass from its concealed position in a long curving path instead of a straight line toward the observer. The eye, of course, does not distinguish the change in the path of the ray, which appears as in a straight line from a point above the horizon, as if the sun were really in that position.

Twilight. The color changes which occur over large portions of the sky, especially the eastern and western skies in fair weather, as the sun

sinks to the horizon and below it are due to the varying effects of the atmosphere on the last rays of the setting sun. These phenomena vary greatly, but usually occur somewhat as follows, especially in clear weather.

A grayish-blue arch rises above the eastern horizon, which is merely the shadow cast by the earth. On it rests a purplish arch, which gradually merges westward into the blue of the sky and fades away as the shadow arch rises.

A whitish, yellowish or even bronze glow encircles the sun as it approaches the western horizon, the upper part remaining visible for 20 minutes after sundown. Just before sundown a bright segment rests on the western horizon, the lower portion of which often is red and the upper yellowish. A purplish glow covers much of the western sky, which disappears as the sun sinks a few degrees below the horizon, and is succeeded by a faint purple glow which covers the whole sky and gradually disappears. At dawn the same phenomena are seen, but in reverse order.

Visibility. Visibility is a term that has come into use with the development of aviation. "Foggy" or "hazy" to indicate obscurity of the air proved too indefinite, and an international scale of degrees of visibility was established, reck-

oned in meters, a meter being nearly 1.1 yards, as follows:

0, dense fog, prominent objects not visible at 50 meters; 1, very bad, limit of visibility under 200 meters; 2, bad, 200-500 meters; 3, very poor, 500-1,000 meters; 4, poor, 1,000-2,000 meters; 5, indifferent, 2,000-4,000 meters; 6, fair, 4,000-7,000 meters; 7, good, 7,000-12,000 meters; 8, very good, 12,000-30,000 meters (about 20 miles); 9, excellent, prominent objects visible beyond 30,000 meters.

Visibility depends upon four factors; the amount and direction of the lighting, the dustiness of the air, the humidity, and the temperature homogeneity of the air. It is usually best in the direction away from the source of light. Other conditions being equal, it decreases as the dust in the air increases. Smoke is a common cause of low visibility about cities, and sometimes hundreds of miles away from its source, in cases of forest fires. Because many of the dust particles take up moisture and thereby become larger when the air is damp, the higher the humidity, the poorer the visibility. Finally, when air consists of masses at different temperatures, as on a clear day when local convection is taking place, light is refracted, or bent, when it passes from one to

another of these masses, and thus is dispersed, so that on an otherwise clear day visibility is low because distant objects are made to appear both faint and fuzzy. When there is haze, visibility may be less with strong light than when the light is shut off by clouds, for the strong light illuminates the haze and weakens the visibility of distant objects. All things considered, visibility is best in the early morning after a clear night following a rainy day.

The Airman's Holes and Bumps. Good air for flying must be free from "holes" and "bumps." When the airman strikes a "hole" his plane drops suddenly. A "bump" acts on it as a raised place on a smooth highway acts on a rapidly moving motor-car.

A "hole in the air" is not a vacuous space, nor one in which the density of air is appreciably less than that around it. It is merely a spot of decreased support. Sometimes it is a downdraught, sometimes it is still air, neither descending nor ascending, and sometimes it is a gust from the rear. When a plane passes from an area of updraught into one of still air or a downdraught, it falls slightly. The supporting current has been suddenly withdrawn. The same thing happens when a plane passes from still air into a downdraught. As it flies from still air or a down-

draught into an updraught it strikes a tangible obstacle and is bounced upward, and the same is true when it passes from a downdraught into still air.

Thus if an airplane is flying over hot, bare ground, where the heated air is ascending rapidly, and then passes over a cool forest where there is no updraught it finds a hole. Speeding onward, when the forest ends and bare plain is again below it, the airplane strikes another uprushing current and gets a bump.

Ordinarily updraughts have a vertical velocity of about five miles an hour, but in a thundercloud vertical velocities exceeding 30 miles an hour sometimes occur. Downdraughts are usually weaker. On cloudy days there are few bumps and holes, because there is little difference in local heating. The airman's worst time in the lower mile or two of air is on still, warm, sunny days, in the hottest hours, when turbulence reaches its maximum of violence.

Winds For Gliding. Students have not entirely agreed upon how birds glide and soar apparently without effort, but recent remarkable glider flights in Europe have indicated that there is very little mystery about it, says the late Dr. C. LeRoy Meisinger, U. S. Weather Bureau expert in aeronautical meteorology. Winds blowing up a slope are

deflected upward, and, therefore, on the windward side near the crest of a ridge are found ascending air currents, often of considerable force. A glider, or motorless airplane, when properly launched and skilfully piloted, can rise on these currents and manœuver indefinitely so long as the wind continues. Records of more than eight hours have been made in Europe, and then the flights were ended by darkness or the fatigue of the pilot.

Many years ago, when the Wright brothers were engaged in constructing their first airplanes, they spent a great deal of time in gliding in motorless planes off the sand dunes near Kitty Hawk, N. C., studying the aerodynamics of the airplane. The Treaty of Versailles, by curtailing the use and manufacture of airplanes in Germany, has made flight in gliders popular in that country, and interest in the sport has spread over much of the world.

Kites and Sounding Balloons. Science owes a great share of its knowledge of the loftier regions of the atmosphere to the kite and the sounding balloon. Without the information which they have brought down from high aloft, much that is known would still be left to guesswork. Kites carrying instruments to record atmospheric pressure, temperature, humidity, and wind velocity, have attained heights of 4 miles, and sounding balloons, conveying similar recording instruments, except

for wind velocity, have ascended nearly 23 miles. Still another type of exploring vehicle is the pilot balloon, carrying no instruments, but observable from the ground, and thereby permitting measurements of direction and movement of the free air. Airmen, too, have helped in this work, but not, of course, to the heights at which the balloons have worked.

Where there are clouds scientists can learn much by observing their physical characteristics, directions, and velocities of motion. But above the loftiest of clouds, the high cirrus, six or seven miles up, there is no way to observe the temperature, etc., excepting by sending up instruments. Human life cannot exist there.

The flight of the freed balloon, like a mammoth toy, with its little instrument basket trailing below, appeals to the imagination. It must go wherever the winds decree, first in one direction, as it feels the currents of a lower level, then in another, again off in yet another course, now slow, now fast, always higher and higher, while all the time the instruments are automatically registering the temperature, the air pressure, and the humidity, gathering invaluable data. Finally the balloon bursts, or, if there are two balloons in tandem, one bursts, and the instruments parachute to earth, usually to be discovered by some one, somewhere,

and returned to the station from which the balloon ascended, perhaps many miles away.

How High is the Atmosphere? The question is sometimes asked, How high is the atmosphere? It has been computed that as far as 20,000 or 25,000 miles from the earth, gases could turn with it without being thrown out into space by centrifugal force. Observations on the twilight arch, which marks the shadow of the earth cast by the sun on the sky after it has passed below the horizon, or before it has risen, indicate that at a height of 40 miles above the sea the air has a density sufficient to scatter light. Measures of meteor trails indicate the existence of air at a height of 200 miles, and auroral streamers visible to heights exceeding 300 miles show there is some atmosphere even at such great altitudes. Actual measurements, however, have not extended much higher than 20 miles, the height to which sounding balloons have gone.

Scientists divide the air into two regions. At an altitude varying from 6 to 10 miles, according to high or low latitude, is found the coldest air, which seems to mark the top of a lower shell of air. Clouds are confined to this shell, which is known as the troposphere. The cloudless upper shell, which extends no man knows how high, is called the stratosphere.

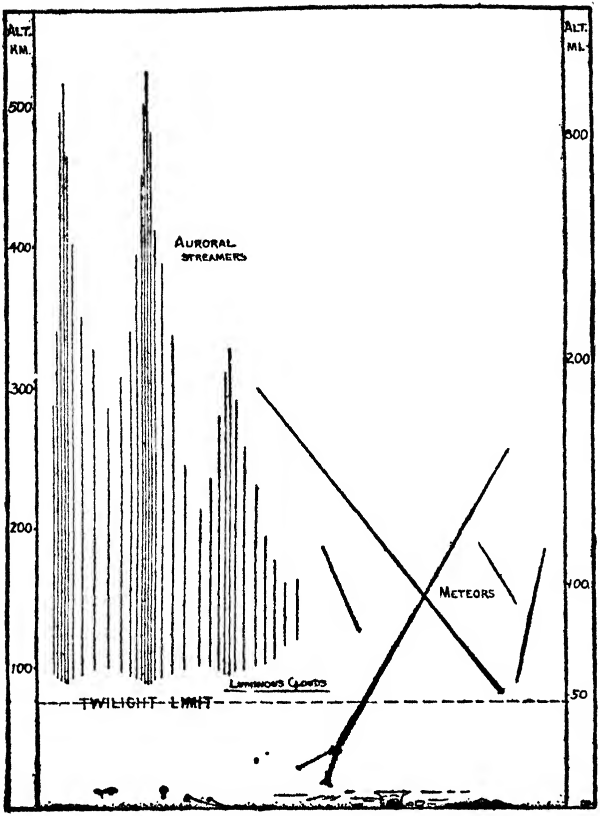


FIG. 33. SOURCES OF OUR KNOWLEDGE ABOUT THE HEIGHT OF THE ATMOSPHERE. In the lower part of the diagram are depicted airplane, manned balloon, kites, sounding balloon, pilot balloon, clouds, and the highest mountains in positions representing the greatest heights attained. Above this very thin layer of the atmosphere, directly explored with instruments, only surmises from luminous phenomena can tell us of the height and characteristics of the air. At levels where they have been observed are shown auroral streamers, the twilight limit, above which the air does not reflect appreciable light from the sun after it has set, luminous (volcanic dust?) clouds, and meteors. (*See* credit, FIG. 23.)

Thin Storms. Although the atmosphere extends perhaps to an unknown height above the surface of the earth, only the lowest layers are subject to the disturbances of storms. The highest clouds do not reach an altitude of more than 10 miles. Similarly, the strongest cyclones do not exceed 10 miles in thickness, while the normal cyclone of the temperate regions usually is less than 7 miles thick. Yet such a cyclone is often 1000, sometimes 2000 miles in diameter! The typical cyclone cannot be likened to a cooky in its proportions, a cooky is far too thick. Rather it resembles a disc about 3 inches in diameter cut from a piece of heavy wrapping paper.

The Aurora. A display of the aurora borealis, or "northern lights," usually begins as a whitish arch of light across the northern horizon. Soon, however, the light brightens and the arch becomes serrated, with straight beams reaching up some distance. Now the beams may move rapidly or slowly westward and change quickly in brightness. If the display brightens, the arch and the beams rising higher in the northern sky take on the appearance of a great curtain the folds of which, illuminated as if by footlights, occasionally move majestically. A reddish tinge may mark its lower edge.

In the most brilliant displays, as the curtain

rises slowly, others appear in the distance. Now the auroral beams may be seen reaching the zenith, and soon one is right under the curtain. The essentially parallel beams of which the curtain is composed now seem to converge in the distance, giving the appearance of a crown or even the spreading wings of a great bird. Soon the curtain is fading into the southern sky. In the rare, great displays curtain after curtain comes out of the north and passes into the south. Occasionally a vivid red occurs over large portions of the sky. Also, at a certain stage the whole display may begin to flicker, as wave after wave of light rises in a fraction of a second from base to top. The fading stages are usually marked by irregular auroral clouds and bands.

Early autumn and early springtime are the periods of most common observation of the aurora. However, on July 6, 1923, a moderate display was widely observed north of latitude 40. As it is practically certain that auroras are caused by emissions from solar disturbances, they are not frequent during 1924 and are not likely to be seen in the South till 1926 or 1927 when the solar activity will again be well on the increase.

Why Meteors Shine. November is a month of meteors, with periods when they add much to the interest and picturesqueness of the heavens. Or-

dinarily, those that appear like stars of varying degrees of brightness flying swiftly across the night sky are but tiny particles, averaging probably only one twenty-fifth of an inch in diameter. Yet their flight is so rapid, from under 10 to over 60 miles a second, that they compress the air in their paths until it is heated to an estimated temperature of from 3,000 to 6,000 degrees Fahrenheit, high enough to volatilize at least the surface material of the meteor and make it highly luminous.

Meteors fly high above the earth; many become visible before coming within 100 miles of the earth's surface, though at such heights the atmosphere has little density. At a height of about 60 miles the density appears to be about one one-hundred-thousandth that of the air at sea level, but even this is many times greater than was assumed before meteor observations were studied. Then it was found that meteors would probably not become luminous at the heights observed were the air as thin as previously estimated. Slight as the density is, it is sufficient in combination with the terrific speed of the flying fragment to produce the incandescent effect which we see.

What Meteors Tell Us. In the last quarter century, kites and balloons have given us a fairly accurate knowledge of the atmosphere up to 20

miles above the earth, for they have carried to that height self-recording instruments which registered temperature, pressure, and humidity. But beyond that height there seems to be little prospect of direct observations. But various luminous phenomena, especially meteors and the aurora, offer scientists excellent opportunities for making deductions of the higher air levels.

Observations of meteors, particularly of their velocities, heights of appearance and disappearance, lengths of paths and their luminosity, are sufficient to permit the computation of their size, the density of the air traversed, and, with other aids, the possible temperatures and composition of the air up to a height of 125 miles. But what the temperatures and quantities and kinds of gases are, at levels above 23 miles, still await direct observation.

FIG. 34. ICE-STORM DAMAGE, WORCESTER, MASS., NOV. 30, 1921. For 72 hours precipitation fell, most of it being rain that froze onto objects touched. Innumerable trees were wrecked by the weight of ice. (C. F. Brooks.)

FIG. 35. AN OLD APPLE ORCHARD DESTROYED BY ICE, WORCESTER, MASS., NOV. 30, 1921. Ice accumulated to a thickness of 2 inches on the upper surfaces of branches. Damage from broken trees and wires in Massachusetts during this storm amounted to several million dollars. (C. F. Brooks.) *See* p. 188.

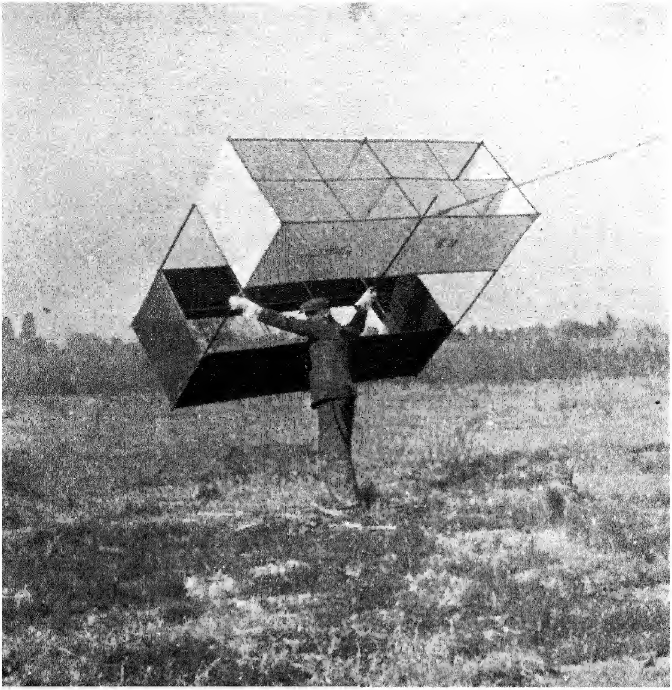


FIG. 36. A SECONDARY KITE. Launching a secondary kite to help lift the kite wire and allow the leader with instruments to rise higher. With several kites in tandem, and with strong piano wire as a line, a kite has been flown by the U. S. Weather Bureau to a height of four miles. Kite flying for meteorological purposes in the United States was first systematically undertaken at Blue Hill Observatory, in Massachusetts, a quarter of a century ago. The U. S. Weather Bureau has 6 kite stations now. *See* p. 218.

PART IV: WINTER

SECTION XIX

WINTER STORMS

When Rivers Are Full, Winter Comes. There is a proverb in the northeastern United States to the effect that "when rivers and swamps are full, winter comes." It is the common impression that winter never starts in after a dry autumn before copious rains have soaked the ground. This impression is not infallible, however, as there are instances on record contrary to it. The conditions in the last three months of 1923 can be taken as a typical illustration of the rationale of such a proverb. Unusually dry, quiet weather prevailed generally in the eastern United States and eastern Canada until late in November. Then a quick procession of heavy rain storms developed which, in the course of two weeks, provided abundant rainfall over large areas and thoroughly prepared the ground in the proverbial manner for the coming of winter.

The onset of these storms with their rainfall seems to have been definitely connected with the establishment of a strong temperature gradient

between the interior of the continent and the relatively warm Gulf of Mexico and Gulf Stream. Usually such a gradient and such storminess become well established by the end of October. In 1923, however, owing apparently, to unusual coolness of the waters of the western Atlantic the contrast sufficient for storms did not become established until the interior had cooled more than usual. Thus the northeast had a dry fall followed by a wet spell and then by winter weather as the flows of cold air from the northern interior of our continent spread over the eastern United States.

Somewhat the same situation prevailed in the Pacific States, and, although there were some unusually early snows in the Sierras, the weather was generally mild and dry until early in December.

Characteristics of the "Low." A "low," the meteorologists' nickname for an extratropical cyclone, or general storm, may be visualized as a vast area where the atmospheric pressure is low, showing on the daily weather map as an oval with its longer axis in a northerly and southerly direction. Its wind velocity is usually moderate, its accompanying cloud area is immense, and rain or snow generally falls. The area of snow or rain and heavy clouds is commonly from 300 to 1,000 miles in length and half as wide.

The winds of a "low" are generally ascending currents crowding in from regions of higher pressure. But this peculiarity exists: the winds do not blow straight towards the center of the "low," but enter it in more or less spiral paths, and, in the northern hemisphere, in a direction opposite to that traveled by the hands of a clock. Thus, winds from an area of high pressure to the northwest enter the "low" from a northerly direction, and those from a "high" in the southeast from a southerly direction.

The southerly airs are relatively warm and moisture laden, and therefore the bulk of the precipitation is in the easterly and southerly quadrants where the air masses are rising over or being elevated by inflowing colder winds of the "low."

The Polar Front. When a low pressure area is passing and the colder west or northwest wind arrives, heralding fair weather, we may say that the polar front has come. It simply means that the blast which originated in accumulations of air in the far north has struck us, its front as tangible in its way as that of a wave of water.

One hundred years ago storms were considered to be the result of a never-ending conflict between polar and equatorial air streams. Later, meteorologists almost forgot this idea, but in recent

years it has again won an important place in meteorological thought. The battle of the winds takes place on what is called the polar front, or the boundary between polar and equatorial air streams, and passes us every time there is a sudden change to warmer or colder. In the first instance, the polar front is in retreat before the onslaughts of an equatorial air stream, while in the latter, the polar air stream is advancing into the equatorial one. Sometimes, however, there is a change only from humid to dry air, or vice versa, without a temperature change.

Winter Storms Move Fast. Winter storms in the United States and southern Canada move much more rapidly than those of summer. The average advance in the cold months is a little more than 700 miles in 24 hours, or nearly 30 miles an hour, while in summer the speed is only 500 miles, or a trifle over 20 miles an hour. The reason for the difference is the greater temperature differences between the north and south in winter. The south is colder during winter than summer, but in nowhere near the same ratio as is the north. Therefore, general pressure differences and the prevailing winds which carry the storm are correspondingly greater during winter than summer.

In the "high" following the winter cold wave

the barometer may stand above 30.50 inches, and occasionally it mounts nearly to 31 inches, far above any normal summer pressure. Also in winter the low pressure is more extreme than in the warm months.

It is because of the great differences in pressure between the "highs" and "lows" that winter winds are much stronger than those of summer. Wind velocity depends upon this so-called gradient, the greater the pressure and the shorter the distance between points of "high" and "low" the stronger the wind.

Types of Winter Storms. Winter storms may be roughly divided into three types, the usual rain or snowstorm, the northeaster, and the blizzard. The usual storm may come with an almost windless, cold, stagnant lower atmosphere, or may be accompanied by gusty winds which drive the rain in sheets or whirl the snow into drifts. In summer the same general weather conditions produce an ordinary rainy day.

The northeaster is a phase of the same type, with strong northeast winds of some duration. This is often a "good old-fashioned snowstorm." In its most intense form it often receives the name of blizzard, but, strictly speaking, this is a misnomer.

The true blizzard is almost unknown in the East.

It sometimes occurs in the Middle West, but its native heath is the Great Plains. It is usually a snow-driving, northerly gale of zero cold. The fierce winds gather up the snow-dust from the ground and whirl it about to such a height that it is impossible to tell whether more snow is forming or not. The penetrating gale and all-pervading snow-dust quickly bring death to those who lose their way in the overpowering wind and bewildering snow-fog.

The Winter Northeaster. The heavy snows of North America usually come with a strong northeast wind. They are the equivalent for the winter of the rainy northeaster of the summer, and their total fall of snow usually depends not so much upon intensity of snowfall as upon its duration. Even a moderate rate of fall will pile up a goodly thickness of snow in 24 or 48 hours. A northeast storm with a snowfall of two inches per hour is worthy of honorable mention, unless it be of exceptionally short duration. But ordinarily the fall is not so rapid. Almost always there is plenty of warning of the approaching storm for, as a rule, it travels at moderate speed and sends its cirrus streamers hundreds of miles in advance.

The cause of the snowfall, whether on the Pacific coast, the Plateau, the central plains, or the eastern states or provinces, is the elevation of moist

air near the freezing point in such volumes that much moisture is precipitated. This is accomplished most readily when a southwesterly current becomes unstable with colder air above, and is forced up and rapidly cooled in large volumes. Precipitation may also be induced if the warm wind meets an obstructing mass of colder and much denser air, and has to rise over it.

The Northeaster's Variations. The approach of the winter northeaster may mean the promise of any one of several kinds of foul weather, all depending upon the temperature that it meets upon its arrival. During its presence the country which it overspreads may be divided into various zones of weather. In the most southerly there may be only rain; in the next zone farther north sleet and rain which freezes on the ground as it falls, forming glaze; next a zone of sleet mixed with snow; and finally in the northerly zone a heavy snowfall. It may happen, however, that the temperature is low up and down the country, in which case snow falls everywhere. Whether or not a coming storm is likely to be marked by rain, glaze, and sleet, or merely snow, is usually indicated by the temperature and the strength of the southerly winds prevailing in the Southern states. The stronger and the warmer these winds the greater is the danger of an ice storm, and the

smaller is the likelihood of a snowstorm; for under such conditions the warm wind, from which copious rains rather than snows are usually precipitated, may ride far north over the cold air near the ground.

Storms Can Clear Too Soon. If a "low" goes by in too much of a hurry, it sometimes requires another immediately succeeding "low" to finish the job of establishing fair and much colder weather. A strong low pressure area may pass so rapidly through the region that there is neither time for much warm air to come far north on its front, nor for much cold air to travel far south in its rear. As a result, after the "low" has passed there is strongly contrasted warm air in the south and cold air in the north not far separated. The situation favors the quick development and rapid passage of another storm. Scarcely before the westerly wind on the rear of the first storm has subsided, cirrus clouds or "mares'-tails" race across the sky from the west or west-southwest. The cloudiness increases, and in less than a day snow is falling. So quickly come, as quickly go! Such snow does not continue for long, though its more intense rate of fall may appear ominous to transportation companies. The wind which may have held in the north-northeast or north shifts to northwesterly and as its strength increases and

the snow begins to drift, the temperature begins to tumble, and the sky begins to clear.

The Winter Thunderstorm. Thunder in winter almost invariably marks a considerable change in the weather. It announces the arrival of the most trying winter weather, the rapidly changeable kind. Near the close of a cold spell the coming of the eastern flank of a warm wind aloft may be marked by a line of thunderstorms where the greatest local contrasts between the cold and warm air masses occur. Soon after, the warm wind may wear its way to the ground through the denser cushion of cold air. Then again, at the western flank of the warm current, where cold air is pushing in, another line of thunderstorms may give warning of the imminence of a cold wave. Temperatures in winter 25 degrees above normal are very likely to end abruptly with a thundering shift of the wind to a cold direction.

The winter thunderstorm is the result of local overflows of cool air aloft rather than of heating below. The night is the usual time for these disturbances in winter, largely because winter nights are longer than winter days. To be awakened by a crash of heavy thunder, and to see by the lightning a downpour of rain, perhaps with hail, soon followed by snow, is to receive a rare though lasting impression.

Snowsqualls of the Great Lakes. The easterly shores of the Great Lakes experience the extreme of snowsquall conditions in the fall and early winter. In fact they are of such frequency and continuity as to affect materially the season's snowfall, which is much heavier in cities like Grand Haven, Buffalo, and Oswego than in Milwaukee, Toledo, and Toronto. The squalls on the eastern shores often occur several days in succession, while the weather on the westerly shores is fair.

The northwest winds coming from the cold regions of the northern interior of the continent are much colder than the water of the Lakes and the air over them to which the water has released much moisture. The cold air naturally descends and forces the warm air upward, and by the time the eastern shores are reached snow flurries are formed. Furthermore, the winds over the Lakes are little retarded by friction and consequently pile up onto the eastern and northern shores more rapidly than the land-retarded air in front can get out of the way. Thus a general ascent of air results as the shore is reached, cooling the air by expansion, in that way causing condensation of snow.

February Has Most Snow. February throughout the eastern United States is the most favor-

able month for snowstorms. Looking at maps of snowfall distribution by months one sees that, notwithstanding its 10 per cent handicap in number of days, the average snowfall of February exceeds that of January over most of the eastern United States, the only portion of North America for which monthly snowfall maps are available.

Why should not the heaviest snowfall occur in January, commonly our coldest month? It is true that the land is coldest in January, but the oceans and the Great Lakes do not cool so quickly, and so do not reach their minimum temperatures till February or even March. A wind from which heavy snow is being precipitated must bring its moisture from some large body of water. In early winter, such winds may be too much warmed by the water to produce snow, and will give rain instead. Heavy snow usually is caused by a well developed, cold "low" moving eastward, accompanied by a very cold, well marked "high" to the north. The snow falls principally with, or rather through, the northeast surface wind between the "high" and the "low." In New England, such a northeast wind off the ocean, though perhaps still generally too warm for snow in January, is colder in February and may favor heavy snowfall. By March, the ocean has reached its lowest temperature, but

the land is becoming distinctly warmer, hence conditions are less favorable for snow than in February. In the case of the British Isles where the ocean temperature is the principal control, the heaviest snowfall may be delayed as late as March or April.

Memorable Snowstorms. Every once in a while some part of North America gets a winter storm which stands far above others for its snowfall. Perhaps the most memorable during recent decades was the storm of March 11-14, 1888, known locally as "The Great Blizzard," though it was not a blizzard in the true meaning of the word. In parts of Vermont, Massachusetts, Connecticut, and eastern New York more than 40 inches of snow fell in three days. Another storm of similar severity was the widespread one of February 11-14, 1899, when the snowfall amounted to 44 inches near Atlantic City and Philadelphia. This appears to have been exceeded, however, by the storm of January 17, 1867, in which the average depth of snowfall reported in Dorchester, Mass., was about 5 feet.

Occasional snowstorms surpassing at some places anything in the recollection of the oldest inhabitant are extremely local in their exceptional depths of fall. That of January 5-6, 1924, in southeastern New Hampshire is typical. At Exe-

ter 36 inches, and at Portsmouth 30 inches, of snowfall was reported, most of it coming from late afternoon to the next morning; Boston, 45 miles south of Exeter, had but 3 inches; Concord, 30 miles northwest, 13 inches; and Portland, 60 miles northeast, 10 inches.

Farther back in history are others. At Norfolk, Va., for example, old records tell of a fall of 60 inches February 4, 1798, followed 10 days later by another of 40 inches.

Similar great storms occur from time to time in the lee of the Great Lakes, in the Middle West, on the Great Plains, Plateau, and even the Pacific coast. A most extraordinary snow- and sleet-fall of 54 inches occurred at The Dalles, Ore., November 17-20, 1921. There are few people in the western mountains in winter to experience the tremendous snowfalls there.

The Old-Fashioned Winter. Place no credence on the oft-repeated assertion that in the northeastern states and southern Ontario the "good-old-fashioned winter" is a thing of the past. The records of three centuries in New England do not show any permanent reduction in snowfall or in the frequency of "old-fashioned winters," though there are series of years, even decades, when unusually snowy winters predominate, and other series when open winters are the rule, thus in the

span of a lifetime giving rise to the impression of a permanently changed winter climate.

Occasionally we have a very mild winter, and so, too, do we have very severe winters. In the old days, mixed with severe winters were mild seasons containing the "green Christmas," which in the old sayings begot a "fat graveyard."

For example, in the northeastern United States and eastern Canada, 1915-1916, 1917-1918, 1919-1920, and more locally in New York and New England, eastern Ontario, Quebec, and the Maritime Provinces, 1922-1923, were cold and stormy winters, while 1916-1917, 1918-1919, and 1920-1921, were unusually open. Several of the past eight winters had snow enough over a wide area to satisfy the demands of the most captious of the "old-fashioned winter" theorists.

Various factors of modern life, aside from the occurrence of actual winter fluctuations, known to occur over long periods of years, are responsible for the belief in a changed winter climate. Among these are the townward drift of the population, the removal of snow from the city streets, heavy traffic on country highways, and the removal of persons to regions having normally lesser snowfall. Also, strongest impressions are those of childhood, when snow "chest high" is only half as deep as "chest high" on an adult.

Severe Early Winter Weather. In marked contrast to the mildness of November and December, 1923, in eastern North America, stood the coldness and snowiness of the same period in the southwestern United States and northern Mexico, and in western, central, and southern Europe. Over the North Atlantic and Pacific are big, high pressure areas, usually centering between latitudes 30 and 35 degrees. During the first half of this winter these "highs" over both the Atlantic and the eastern Pacific seem to have been unusually strong and several hundred miles north of their usual winter positions. Seemingly in consequence of this displacement, great masses of air entered the plateau regions of the United States, piled up and overflowed strongly southeastward and southward. Hence, northers were frequent in California, Arizona and New Mexico, and unusual cold, snow, and rain occurred in the southern plateau and northern Mexico.

Meanwhile, western and southern Europe were experiencing even stormier weather than our Southwest. Tremendous floods, unprecedented snowfalls and avalanches, and westerly to northerly gales featured in European dispatches through November and December.

The Blizzard. There is a sharply defined difference between a heavy snowstorm and a bliz-

zard. The characteristics of a blizzard are a gale of wind, zero cold, and drifting, powdery snow. The wind may not have been accompanied by actual snowfall, yet to the height of several hundred feet the air may be filled with swirling masses of snow, whipped up by the gale. As observed from a lofty elevation, the sky above may all the time be clear and blue. The snow covering, intensely cold and dry, submits to the pulverizing influence of high winds.

This phenomenon is not common in the eastern part of the country. Though the wind in a blizzard usually comes from the north it may be westerly instead. One of the worst blizzards that ever struck the Ohio Valley, that of January 12, 1918, came with a southwest gale, during which the mercury fell to 20° F. below zero. On the northern Great Plains the blizzard descends from the north with frightful violence of wind, chokingly full of snow as fine as dust, with the mercury at dangerously low levels. It is not surprising that in such blinding storms as these, people stray from beaten paths and sometimes perish only a few feet from a house.

The Proportion of Stormy Days. The total amount of rainfall and snowfall is not the only measure of dampness as it affects a community. Some regions have rains of such intensity and

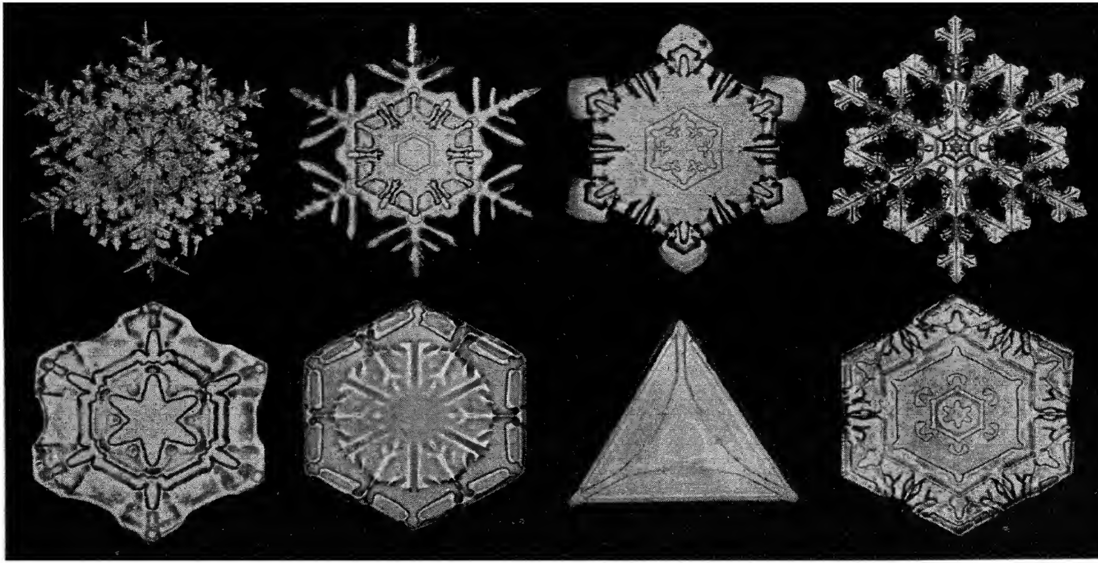


Fig. 37. Microphotographs of Snow Crystals. (W. A. Bentley, Jericho, Vt.)
See pp. 245-246.

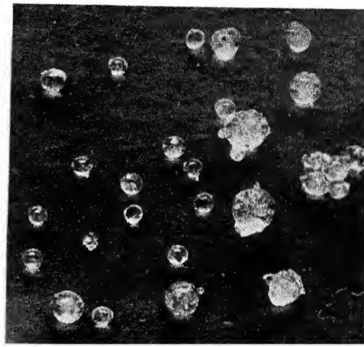


FIG. 38. SLEET. Sleet pellets are formed mostly from the refreezing of partly melted snowflakes. In winter the cold air next the ground is often overrun by a warmer wind in which snow formed higher up may partially melt before plunging into the cold layer below. *See* p. 247.

FIG. 39. SLEET. Sleet shows all gradations from but partly melted refrozen snowflakes to ice droplets that do not surely give any indication of snowy origin. Few pellets do not show included air bubbles—remnants of snow. (Photos by W. A. Bentley, Jericho, Vt.)

snowfalls of such depth, in a day or two, that the annual fall is much greater there than in other areas with as many rainy or snowy days. Other regions have more days of stormy weather, with no greater precipitation, and perhaps even less in the aggregate.

A great many places in the United States have measurable precipitation on about one-third of the days of the year. Boston, New York, Philadelphia, and Washington have about 130 such days. Chicago averages 126, St. Louis and St. Paul 114, Topeka and Galveston about 100, Seattle 156, Portland 164, San Francisco 71, and Los Angeles only 36. Buffalo is less fortunate with 170 days with measurable precipitation, its excess over other eastern cities, not similarly located, coming mostly from the numerous days of light snowfall with winds off Lake Erie.

In general, the amount of precipitation per rainy or snowy day is much greater in the moist South than in the drier North or West, the contrast being most marked in winter. Frequent snows and rains occur where numerous "lows" pass, or on windward slopes of mountains or leeward shores of lakes or the ocean; while intense snows and rains come where there is abundant moisture and strong "lows" or strong, local upcurrents to precipitate it.

SECTION XX

SNOW

Clouds Are Lower in Winter. Most types of clouds are lower in winter than in summer. Similarly, clouds of the polar regions average very much lower than those of the tropics. The difference in height between summer and winter amounts to about 10 per cent for the upper and intermediate clouds, and 40 per cent for the lower ones. The reason for these differences is one of relative humidity. The greater the humidity the less is the cooling required to cause condensation, and therefore the less the amount of vertical movement which can take place before clouds form. In winter the relative humidity is generally higher than in summer. This is because the snow-covered or wet land surfaces are almost constantly not only evaporating moisture but also chilling the air in winter. Moisture is being discharged into air at a temperature too low to allow much vapor, so the air is nearly saturated, or in other words, the relative humidity is high most of the time in winter.

The lowness of winter clouds makes winter fly-

ing more difficult than summer aviation. The low elevation also makes it easier for snow to occur, there being but little opportunity for evaporation to occur before the snowflake reaches the ground. And, what is very important in great highlands, as in interior Asia, the lowness of clouds in winter makes possible the wintertime use of highland pastures above the snows.

The Making of a Snowflake. Snow is formed by the condensing of the moisture of the air in a freezing atmosphere. The vapor does not instantly become snow, as we see it, but grows into flakes through a process of gradual crystallization, forming the exquisite snow-stars, which every one should view under a magnifying glass in order to have a realization of a loveliness which the highest art of the jeweler can do no more than imitate. They take on a very wide variety of crystalline form, all hexagonal, with rarely the appearance of a 12-pointed star or a triangle.

Photography through a microscope has classified hundreds of highly individualistic designs, fashioned as the freezing moisture responds to the different conditions attending the birth and growth of the crystals. The initial phase is usually a more or less solid disc or an open-work hexagon, and further development is toward a filling of the inner interstices, with an inconceivable va-

riety of branching. These are the flat crystals. There are other forms, among them the columnar, and some like delicate, collar buttons. Wilson A. Bentley of Jericho, Vt., has made thousands of microphotographs of snowflakes, no two of which are alike.

Electrified Snowflakes. During snowstorms delicate electrical instruments show great changes in electrical potential even from minute to minute. This may be partly from friction of snow driving along the ground, but it appears likely that it is chiefly owing to the fracturing of flakes, corresponding to the electrification of splitting raindrops.

When snow forms in an upward current of appreciable velocity, only the largest and densest flakes may make appreciable progress earthward. As with breaking raindrops in an upward wind, it seems probable that with any breakage of snowflakes the heavier fragments, falling low in the cloud, will carry an excess of positive electrons, while the lighter fragments, remaining above, will carry more of the negative electrons.

Since the strength of convection in winter is much less than that in summer, while also the breakage of snowflakes occurs much less readily than that of oversized raindrops, and the relative rates of fall of larger and smaller snow

fragments do not differ so much as those of raindrops, there is in winter but rarely a degree of electrical separation that is so common in summer. Thus, winter thunderstorms are rare.

Sleet. Sleet consists of ice pellets which are frozen raindrops, or partly melted snowflakes refrozen, due to the falling of the precipitation through a cold layer of air near the surface of the earth. We hear it rattling on roofs and window panes. Usually the pellets are no larger than duckshot, but sometimes they are the size of a dried pea. Sleet has been reported as hail so often that the Weather Bureau has issued an explanatory pamphlet calling attention to the fact that ice pellets of sleet differ materially in structure from the layered hailstones. Sleet may contain enough air to give it a whitish, opaque appearance, lending it the semblance of small hail.

Sleet may occur when a cold current flows under warm, moist air, or when a warm southerly wind flows over the top of very cold surface air. Sleet storms are apt to come in the morning when the surface temperature is at its minimum, but this is by no means always the case. Sleet is often mixed with rain, when it forms as an ice-coating on the ground, making a more or less pebbly surface.

The Snowfall About the Great Lakes. December is the snowiest month in the northern Lake

region. There is still much open water to moisten the passing air and there are frequent, cold, west and northwest winds to drive under and elevate the air over the Lakes. Even the small obstruction offered by the low, eastern shores does its part in forcing the strong Lake winds to rise, thereby cooling them further and increasing the snowfall. While people on western shores enjoy clear, cold, windy weather, those on the eastern shores must endure a chilly, bleak wind, full of driven snow.

The differences in total snowfall resulting are remarkable. To take the extreme case, Port Arthur, Ontario, on the northern shore of Lake Superior, averages 31 inches annually, while the town of Adams Center, N. Y., near the eastern end of Lake Ontario and about 50 miles north of Syracuse, has nearly 185 inches, with a single season's record of 334 inches which may be contrasted with Port Arthur's best year of 70 inches. Other examples are in the average snowfalls of 49 inches in Duluth, 136 inches in Calumet, 36 inches in Chicago, 65 inches in South Bend, 29 inches in Sandusky and 78 inches in Buffalo. The weather maps of November to January show many examples of the individual differences that, taken together, make up these totals.

Wet and Dry Sides of Mountains. Up-hill winds tend to be cloudy and rainy or snowy, while

down-hill ones are usually clear and dry, the reason for the difference being simply that rising air cools by expansion and thereby reduces some of its vapor to clouds and rain or snow, while descending air warms by compression and becomes relatively drier. The weather of early winter, 1923-24, afforded numerous examples in addition to the chronic wetness or snowiness of the west faces of our western mountains, and the dryness of west winds on the Great Plains and Atlantic slope.

The unusual northers of November and December in the Southwest brought abundant rainfall to the southern end of the Great Valley of California and continued dryness to the southward slopes beyond. The west-northwest wind New Year's Day caused half a foot of snow to fall at Syracuse, N. Y., where the wind had to rise over highlands, but no more than an inch at places ten miles and more farther west. In southern New England the same wind was clear and snowless.

The White Storm. Damp snow and snow of ordinary dryness falling on the limbs of trees, wires and poles, whose temperature is slightly above freezing, is very apt to cling to them, and the weight of the accumulations may become sufficient to break branches and snap wires, causing not only material damage but troublesome inter-

ruption of communication. Such a condition is sometimes called a "white storm."

A temperature materially below freezing following such a storm, converting the water portion of the burden into expanded ice may result in great damage to shade and forest trees and fruit orchards. Branches which will bend freely at higher temperatures become brittle under the influence of freezing and break easily when subjected to so severe a strain as a load of ice. The expansion as wet snow freezes may be an appreciable factor in bending branches downward, for this freezing is on the upper sides of the branches.

Winter Dark Days. In winter-time, smoky cities are particularly likely to experience dark days, from the concentration of soot and dust in the lower air. Requirements of heating and lighting in winter increase the smoke production of a city; and the humidity, usually higher than in warm weather, favors the production of dense, smoke and water clouds. Not only have we more smoke in winter than in summer, but often less chance to get rid of it. If there is no appreciable wind, there is little tendency for different layers of air to mix, for in winter the lower atmosphere is typically in a state of stable equilibrium with the colder, heavier air below. The smoke and dust, then, instead of being carried aloft and dissipated

by convectional currents, as in summer, remain in the stagnant, lower air where they originated, forming a heavy pall. A slightly warmer air current arriving aloft will accentuate this condition by forming a definite "lid" in the atmosphere against which sooty clouds mushroom and form a black ceiling.

When snow occurs under such conditions extreme darkness results.

Snow is Mostly Air. Even a heavy snowstorm does not represent a great amount of water. The usual reckoning of newly fallen snow is one inch of water to 10 or 12 inches of snow. When the snow is light and fluffy the ratio is even greater. Snow is very largely air, varying from three parts of air to one of ice crystals, to a proportion of 30 to one. This is for newly fallen snow. As it mats down and becomes more nearly a solid sheet of ice the proportion of air decreases very much, so that the water content per cubic inch is much greater. The snowshoer or the traveler on skis can roughly gage the volume of air in snow by the depth to which he sinks into the surface. On newly fallen snow in the far north and on high mountain slopes the web of the snowshoe must be of large area to support a man, merely because the snow contains so much of air and so little of ice.

The January Thaw. The January thaw is so

named because in most years the first real thaw of winter comes in that month. There has been a cold wind, probably accompanied by snow or an ice storm. Next a rise in temperature is experienced, and a southerly wind arrives aloft, causing several hours of fog. Finally the damp, warm, south wind reaches the ground.

The wind does not lap up the moisture of the snow surface as is commonly supposed. The contrary is the case. Instead of increasing its own moisture content, the wind becomes drier, for it leaves its moisture behind it, condensed on the snow, just as dew is deposited from warm moist air on the cooler ground. And in condensing it gives forth heat, which takes effect in increasing the melting of the snow into water, which runs off in streams. As a rule a January thaw, and the thaws which come afterward in February and March, continue uninterrupted but one or two days, ending as an area of high pressure brings with it cold air which lowers the temperature to wintry levels.

Chinook, the Snow-Eater. The Chinook is the warm wind of the Northwest. Its name is that of a tribe of Indians from the direction of whose camp the warm southwest wind reached the trading post, Astoria, at the mouth of the Columbia River. The use of the name soon spread to all

warm winds in winter in the Northwest, and now the term is applied mostly to warm winds descending onto the Great Plains after passing over the Rocky Mountains. The warmth of these Chinooks is largely the result of latent heat liberated during the copious precipitation of rain or snow on the windward slopes of the mountain ranges. This latent heat greatly hinders the cooling of the rising, expanding air, allowing it to reach the mountain crest at a moderate temperature.

Descending from there, the air is warmed considerably by compression until it may be 15 or 20 degrees warmer when it reaches the plains than it was at the same level on the windward side. So much moisture has been removed that it has become very dry. As it strikes the snow-covered country the temperature frequently rises 20 to 40 or more degrees in 10 or 15 minutes. In one case, the rise was from 13° F. below zero to 38° above. Under the dry blasts the snow disappears as if by magic, for it evaporates as well as melts. Whole herds of cattle have been saved from starvation by the timely removal of deep snow.

The Chinook is the same as the foehn wind of Switzerland, and similar winds are found in Greenland and New Zealand, in fact, wherever a mountain chain or highland and the strong winds of passing low pressure areas are associated.

SECTION XXI

WINTER RESORTS AND SPORTS

The Ideal Climate. Any one living in the northern or central United States is likely to hear a good many hard things said about the climate, in the course of the year. It is too cold, or too hot, or too damp, or so changeable you never know what to expect next. It may be well to remind those who complain that the "two main areas in the world with climatic conditions most favorable to human activity appear to be western Europe and this portion of the United States."

Professor Ellsworth Huntington, of Yale, has studied the question of what constitutes an ideal climate. We must, he says, avoid continued extremes of heat or cold. An average winter temperature around 38° F. and a summer average not far from 60° are thought to be very desirable. Such conditions occur in England and on our Pacific coast. Excessive dampness or dryness, as well as persistent extremes of temperature, is not to be chosen. But a climate may be too equable; it is well that the temperature should change de-

cidedly from season to season, from day to day, and from day to night.

The extreme monotony of weather in the tropics or the polar regions is enervating or depressing. So, too, monotony prevails in the vast regions of central Asia not crossed by storms. The United States, however, is blessed with plenty of storms to give variety; indeed, the Great Lakes region of the northern United States and southern Canada can pride itself on being among the stormiest lands in the world! While California has a delightful climate for outdoor activity through the year, it is a bit too consistently good. A little really bad weather, now and then, is relished by the wisest men, who appreciate the value of relaxation. Hence Professor Huntington is ready to champion Boston with its east winds and London in spite of its fogs.

Our Weather Travels. One may stay at home and yet travel quite a bit climatically. Mr. J. B. Kincer of the Weather Bureau has pointed out the extent of our involuntary climatic travels. In winter, a difference of one degree F. in normal temperature corresponds to a distance of about 27 miles north and south, barring topographic irregularities. In summer a difference of one degree F. may correspond to a north and south distance of anywhere from 55 miles in the northern

portion of the country to 500 miles in the south. Thus, the people of Washington, D. C., to take extreme cases, spent the mild January of 1890 in a climate characteristic of northeastern South Carolina; in the cold January of 1918 they were less fortunate as they were forced to sojourn in southwestern Maine. In July, 1891, St. Louis enjoyed moving to southeastern Minnesota, while, on the other hand, in 1909, it migrated so far south as to go beyond the Gulf coast. To show in detail the erratic nature of our weather travels, Mr. Kincer chose the weather at Washington during a 10-day period in January, 1921. The schedule of the weather train was as follows:

January	17th	At home, *i.e.*, weather normal for Washington at that season.
"	18th	Arrived Eastport, Maine.
"	19th	Trip to New Brunswick and return.
"	20th	Arrived in Washington.
"	21st	Arrived Wilmington, N. Carolina.
"	22nd	Arrived St. Augustine, Florida.
"	23rd	Passing north through Savannah, Georgia.
"	24th	Passing north through Richmond, Va.
"	25th	Arrived southwest Maine.
"	26th	Stop over two days in Maine.
"	27th	
"	28th	Passing through Washington en route south again.

It falls to the lot of the weather forecaster to find out these erratic routes in advance if possible and to announce the schedule to the traveling public.

December Weather. Cold waves become more frequent and severe during December, particularly in the interior and northern states, and very low temperatures occasionally occur. In degrees F. the Weather Bureau's low record for the month is 50 below zero in north-central Montana, and from 10 to 15 below have occurred as far south as central Oklahoma, and 5 below in portions of Tennessee and North Carolina. The lowest temperature ever experienced in December along the Gulf coast was 14° F. above in extreme northwestern Florida and southern Alabama.

The coldest average temperatures for December, about 10° F., are found in northeastern North Dakota and Minnesota. To the southward the average increases rather rapidly to 55° along the Gulf coast. On the Atlantic seaboard, Boston averages 32° for the month, New York 35°, Philadelphia 36°, Washington 37°, Atlanta 45°, and Key West 70° F.

East of the Great Plains the heaviest precipitation is in the region from Arkansas and Tennessee south to the Gulf. The rainy season of the Pacific coast is well established. Snowfalls are frequent in the northern states, particularly in

parts of Michigan and in central New York and New England.

January Weather. January is usually the coldest month of the year, and in the northern states in general is the month of greatest snowfall. It enjoys these distinctions in common with the first half of February. In the United States the coldest weather, as a rule, occurs in the extreme northern parts of North Dakota and Minnesota, where the average temperature for the month is slightly below zero F. The adjoining provinces of Saskatchewan and Manitoba are the coldest of southern Canada. The averages are generally below freezing from southeastern Pennsylvania, the Ohio River, south central Missouri and southern Kansas northward, but are above 50° F. in the immediate Gulf coast sections, and above 60° in the southern portion of the Florida peninsula. On the Pacific coast they range from 40° in the north to slightly above 50° in the south. Going south from the coast of southern Maine to Florida or from Duluth to New Orleans the average increase in the normal January temperature is about one degree for a little less than 30 miles, or about one and one-half degrees for each hour of travel on an express train, when going due south.

In the northern interior sections of the country

very low temperatures are sometimes experienced in January. In Minnesota, the Dakotas, and Montana from 40 to 50 degrees below zero have been recorded, while 25 to 30 below have been widely experienced, even in southern Ontario and central New York. The lowest temperature ever recorded at a Weather Bureau station in any state was 63 below in eastern Montana in 1885. Along the central and southern California coast the lowest record is but 3 degrees F. below freezing.

Heavy snows occur in the Pacific Coast mountains and high elevations farther east, and from the Great Lakes eastward. To the southward the snowfall decreases rapidly to 5 inches in southern Maryland, eastern Kentucky, and southern Illinois.

February Weather. Though on February 1 spring is not many months away and much of winter has passed, there remains the month of February, one of the coldest of the year. In its closing days there may be an appreciable warming up, but its average temperature does not differ greatly from that of January. Cold waves frequently sweep down from the Canadian Northwest and sometimes bring extreme frigidity. During the memorable cold wave of February, 1899, the zero F. temperature line was carried southward in some places to the Gulf of Mexico. Not only is

the month a cold one, but in the northern states it often has heavy snowstorms.

The lowest normals or averages are about 5 degrees above zero in the northern parts of Minnesota and North Dakota, while to the eastward over the northern Lake region and the interior of New York and New England they are from 10 to 15 degrees higher. To the southward there is a progressive increase in normal to about 32° F. in southern Kansas, the extreme southern portions of Indiana and Illinois and central Maryland. In the Gulf districts the February averages are between 60° and 65°, and on the tip of southern Florida above 70° F. On the Pacific coast the February average ranges from about 40° in the extreme north to 55° F. in southern California.

Ocean Temperatures. The ocean is the great conservative element in climate. The farther a place is from it, or the more completely shut off by mountains from the moderating influence of its surface, the drier and more extreme is the climate.

The ocean surface temperature can change but slowly. On clear days a large proportion of the sunlight is reflected from it, and about one-half the remainder is required to prevent a fall in temperature resulting from the considerable amount

of evaporation from the surface. The remainder, averaging only about one-quarter of the light that fell upon it, penetrates and spreads its heating influence through a layer hundreds of feet thick. Mixing caused by the increase of salinity and density of the evaporating surface water and by the mechanical action of wind also restricts the surface heating. Water requires more heat to raise its temperature than does almost any other substance. So the whole effect of strong sunlight is not sufficient to raise the surface temperature of the ocean more than about one degree in a day.

At night when a surface layer gets cooler than the water below, it sinks because it is denser, and warmer water takes its place. Thus cooling at night is slow. Naturally the winds from the ocean are usually cool in relation to the hot land in summer, and warm in relation to the cold land in winter, and at all seasons, and especially in winter, the ocean wind is a humid wind.

Coast is Warmer Than Inland. Regions immediately bordering upon the Atlantic coast, and particularly islands and promontories, the one encircled, the other nearly surrounded by the ocean, have milder winter climates than commonly are experienced inland. The reason is the dominating effect of extensive, relatively warm water surfaces, instead of the chilling influence of snow-

fields or frozen, bare ground. Because of its great depth and enormous amount of stored heat the sea does not, in middle latitudes, cool rapidly enough to fall to freezing temperature, which in the case of salt water is 28° F., instead of the 32° at which fresh water crystallizes.

For example, the ocean water off Atlantic City averages about 70° in summer and 40° in winter. Off Boston the average is 60° or thereabouts in summer and 30° F. in winter. The winds that strike an island such as Nantucket or Marthas Vineyard must first pass over surfaces not excessively cold, while in regions inland all winds must blow over snow-covered or frozen ground, both of which commonly are much colder than the ocean. Therefore, these islands have what is known as a marine climate, and the same is true to a lesser degree of the land which lies close to the coast. In a marine climate in mid-latitudes much of the winter precipitation which inland falls as snow takes the form of rain, and such snow as does fall is likely to melt quickly.

California's Coastal Climate. The temperate climate for which our Pacific Coast is noted is largely owing to the Japan Current drift from which the prevailing winds blow. On approaching the continent this drift water spreads northward and southward, the dividing zone being usually

at about the latitude of San Francisco. The northward branch, though slightly cooler than the southward one, is warm compared with the average temperature for its latitude. Therefore, it has a moderating influence on the climate of the adjacent land. The mountainous coast against which the moist, prevailing westerly winds blow is usually not warm enough to prevent rainfall due to cooling by expansion as the air rises over the mountains or stagnant cold air.

The influence of the southward branch of the drift, which becomes the California Current, is a cooling one, resulting in much less rainfall than farther north. The air when blown landward from its surface becomes warmer over the land and thus it is able to retain all its water vapor and still be eager for more. Where high mountains stand in the way, however, the great expansional cooling is more than a match for the land's heating, so much rain and snow are there precipitated.

In the winter, when the land is receiving its minimum of the sun's heat and has become colder than the slowly cooling ocean, the effect of the cool current which then is warmer than the land may be like that of the warm drift farther north. Thus, in winter, California receives rains and snows like those of other regions farther north, while in summer the warmth of the land extends the rel-

atively dry conditions normal to southern California into Oregon and Washington.

Florida's Winter Weather. For its mild winter climate Florida owes as much to its peninsular character as to its subtropical latitude. Flanked by the Gulf of Mexico on the one side and the warm waters of the Gulf Stream on the other, it possesses the elements of a marine climate. In summer it has the trade winds, and is not subjected to the passing "highs" and "lows" which traverse the continent from west to east usually much farther north. But in winter its weather passes in much the same succession as in the rest of the United States, but on a milder, sunnier plane.

Florida does not wholly escape the influences of the northern winter. On occasion snow falls. Once in many years a north wind descends with a cold so intense as to cause a great freeze, which is the nightmare of the owners of orange and grapefruit orchards and the market gardeners. Only the southwestern keys at the very tip of the peninsula can boast of never having had a frost. But the state suffers far less from winter weather than do the sister states bordering on the Gulf to the westward, chiefly because of the warming influence of the sea.

Dry Cold of the North. In the extreme north-

ern regions of the United States and in southern Canada and on the western highlands a dry cold is experienced which often is endured without great discomfort, even when the mercury is well below zero, while a much higher temperature farther south, especially along the coast, may bring with it a penetrating chill which is hard to endure. The air of the north is dry on a clear day, otherwise its moisture would quickly condense in so cold an atmosphere. But the dryness itself is not the real cause of comfort. It is the windless, clear atmosphere, that usually characterizes the days of lowest temperature. Such a condition is essential to the development of a very low temperature after a wind has brought in a large mass of cold air.

During the day the heat of the bright sun has an appreciable warming effect upon outer clothing and exposed parts of the body, and both day and night the absence of wind prevents the cold air from working in beneath garments and stealing away accumulated body heat. Wind, too, acts to cool the skin by evaporation, and its absence is thus a negative warming influence. But let this same dry air strike as a blast against the body and penetrate through the crannies of clothing and it is cold enough.

Winter Weather in Eastern Canada. Regions

cool enough to attract the summer vacationist can often also meet the requirements of the lover of winter sports. The St. Lawrence Valley is noted for its abundant snowfall which reaches an average of 10 feet a winter in some regions. Moreover, its winter climate is, in some respects, an equable one, for it lacks the excessive cold usually associated with regions which are ice-bound and snow-bound five months of the year, while at the same time winter warm spells are rarely sufficiently pronounced to make traveling uncomfortable either from softness under foot or from too much warmth in winter clothing. In fact, the winter climate of eastern Canada is often the subject of enthusiastic comment on the part of visitors.

Winter Snow and Winter Sports. A map showing the distribution of skis and snowshoes, sleds, and toboggans would give some idea of the usual depth of snowfall. In Canada and the northern United States where the snow is too deep for small sleds in midwinter, except on roads, the coaster relies largely on skis and toboggans, which will carry him successfully over any depth of cold, dry snow. Even he who would walk, except on beaten paths, must take to snowshoes or skis. Considerable labor is required to keep ponds free of snow for skating. The cold is so protracted

that elaborate ice palaces and snow figures may adorn winter resorts.

In a region somewhat farther south where the amount of snow on the ground is more variable, the greatest variety of winter sports is afforded. For coasting, sleds are used most commonly, but the really snowy winter will bring out a good flock of skis and toboggans. Snowshoeing, being the chief outdoor diversion for the sedate and cautious, will persist in spite of lack of great depth. Skating is often good. In most of the southern United States, however, snowshoes and skis arouse curiosity. Only the sleds and skates appear, and even these must spend much time in storage awaiting their coveted opportunity.

SECTION XXII

WINTER SUNSHINE

The Shortest Day. At the winter solstice, about December 22, the end of winter is in sight. It is the time of the turning of the sun. From then on each day will be longer. Spring seems to be near. We can face the knowledge that as "days grow longer, cold grows stronger," with a greater degree of equanimity because each day, no matter how low the temperature, there will be the cheering influence of longer hours of sunlight.

Thence the progress of the earth in its orbit will for six months turn the northern hemisphere of the earth more and more toward the sun. Far in the north, beyond latitude 67, the sun will probably not be visible to-day, and at the northernmost human habitation in N. W. Greenland near where Macmillan recently wintered, only faint twilight may be seen in the south at noon. At latitude 45, from Maine through southern Ontario, Michigan, and on to Oregon, the sun can shine less than nine hours, while the night is 15 hours long. At latitude 30, through northern Florida and the Gulf Coast, there can be a little more than 10 hours

of sunshine. With lengthening days we can feel assured that the sun's heat will eventually count against the cooling at night and bring the spring.

Days Grow Longer, Cold Grows Stronger. The coldest weather of winter is by no means in the period of shortest days. It comes as January is beginning to decline, and in February. There are three reasons for this. One is that the ground continues to give out more heat than it receives from the sun for many days after the winter solstice. In fact, it is not until late in January that a balance is struck, when the amount of heat received by the ground equals that which it radiates and loses in other ways. By February 1, on the average, the season turns, so far as the gaining of heat by the ground is concerned. But the influence of the snowfields in regions which have them still exists. As snow increases in depth it becomes colder at the surface and has an important effect upon temperatures of the air. The third factor is the increasing cold of the far north. Lying in the long winter night, receiving absolutely no heat directly from the sun, the accumulated cold air overflows now and then into more southern regions, such as Canada and the United States. Therefore, in spite of the lengthening days, it is not until the last of January, for much of the United States, that the mercury begins to

average higher. It is truly said that when the days grow longer, the cold grows stronger.

Refraction Shortens Polar Night. The phenomenon of the bending of solar rays, called refraction, has an appreciable effect upon the length of day. For example, the territory covered by the polar night, that is, where at some season the period from sundown to sunrise exceeds 24 hours, does not begin at the Polar circle of 66½ degrees but at 67 degrees latitude. Likewise, when the sun is vertical over the equator, the day is not 12 hours long but 12 hours and 7 minutes. The reason is that while the sun is still below the horizon at sunrise and after it has set at night it is still visible to the eye and casts its light upon the earth. The angle of this refraction is usually small, but at times a cold, dense layer of air greatly increases it.

An Antarctic explorer records that one winter, on the second and third days after the sun had set for its night of two and a half months, it reappeared at noon as a distorted half disc, shedding its feeble but welcome rays on ice-floes, bergs, penguins, ship, and men, who saw the sun which was astronomically below the horizon. A cold wind from the Antarctic ice-cap had bent the rays to such an unusual degree that instead of passing

out to space they came to earth in a long curving path.

Day of Intensest Sunlight. January 2, the earth receives most heat from the sun, for we are then nearest it, only 91,340,000 miles away. The sun occupies a bigger part of the sky as we see it, and sends us heat about 7 per cent more intense than if it were at its greatest distance, 94,450,000 miles.

We do not get the full benefit of this greater intensity, however, for the days of winter are short and the sun's rays strike slantingly. Furthermore, even such sunshine as we do get is largely lost when there is snow on the ground, for its heat is reflected off into space, as much as 70 per cent of it from new snow, and what is absorbed cannot raise the temperature of the snow surface above 32° F., owing to evaporation and melting. Therefore, the sum total is cold weather.

Notwithstanding, our winter climate in clear weather is made notably warmer, whatever the air temperature may be, because of this greater intensity of sunlight. Fortunate it is that the most peopled hemisphere has now, and will have for a few thousand years more, the nearest sun in the coldest season. In the southern hemisphere, though, the reverse is the case, and the climates

there would be more severe than they are but for the vast expanse of the heat-regulating oceans.

The Black-Bulb Thermometer. If one should give the bulb of an ordinary thermometer a coating of lampblack or other opaque black substance and expose it to bright sunshine on a quiet day when the mercury stands, say, at 10° above zero F., the instrument would probably register 60° or 70° F. This would be a crude type of black-bulb thermometer, an instrument now seldom used in the United States but more generally in Canada and Europe. It measures what is sometimes called "sun temperature." A black overcoat exposed to the sun at the same moment would have much the same high temperature, because it was black. A white garment would register very much lower. For example, on a bright winter afternoon when the air temperature was 28°, a piece of a black cat's fur frozen in a snowdrift had a temperature of 62°, while soiled white fur adjoining had a temperature about 10 degrees lower. The black absorbs the heat, the white reflects much of it.

The black bulb thermometer of science is a standard thermometer with a blackened bulb enclosed in a vacuum tube. Because it is enclosed this is more accurate than the makeshift device

referred to, because the wind is kept out. But the principle is the same. The heat absorbed gives a much higher temperature than that of the surrounding air.

Arctic Explorer's Sun-Heated Bag. The heat-absorbing power of dark colors, especially of black compared with white, as applied in clothing both summer and winter, was happily made use of by DeQuervain who crossed the ice-cap of Greenland in the summer of 1912. The problem of drinking water is always a serious one in polar regions where the temperature seldom rises above freezing, especially in the 7000 to 10,000 foot altitudes of central Greenland, where thawing never occurs. But DeQuervain cleverly overcame the difficulty.

He attached a V-shaped pocket of waterproof black cloth to the sunny side of his sledge, where it would receive the direct rays of the sun, which was shining most of the 24 hours. When the air temperature was well below freezing, that of the bag was found to be 88° Fahrenheit. Thus, he readily melted all the snow needed. This device demonstrates most strikingly the heat advantage of dark clothing.

The Groundhog Superstition. February 2 is Candlemas Day, a feastday so old as to ante-

date the Christian era, for the ancient Romans selected the date to burn candles to their goddess Februa, mother of Mars. Superstition has it that

> If Candlemas be fair and clear
> There'll be twa winters in the year.

Out of this traditional belief has grown the legend of the groundhog, also widely known as the woodchuck. This little animal is supposed to waken from his long winter sleep on Candlemas morning and crawl out of his burrow to view the weather. If he sees his shadow, the story says, he goes back for another six weeks or so of sleep, for the winter has a long way to go before giving place to spring. If, on the other hand, the sky is dull so that he casts no shadow, then it is said he will remain up and spring will come early. As a matter of fact, on a February 2 in the northern United States the woodchuck is apt to have a couple of feet of snow and ice over the opening of his burrow, and would have to do some tall digging before he would have a chance to cast a shadow. It hardly needs stating that the weather of any one particular day of a year can not indicate the weather of the weeks to follow.

SECTION XXIII

WINTER COLD

Why Thermometers Disagree. When on a cold winter morning the thermometers of a neighborhood disagree it does not follow that any one of them is inaccurate to the extent of their differences. An accurate thermometer must be exposed in a shelter or whirled through the air or vigorously fanned to measure correctly the air temperature. The reason for the fanning or whirling is that a much larger quantity of air is thus brought in contact with the bulb and the exchange of heat by conduction is thus increased.

If an instrument is on the side of a heated building the indication in calm, cold weather may be as much as five degrees too high. A thermometer lying in the shade, even several feet above the ground will, in clear weather, read one or two degrees F. below the air temperature, and on the other hand when the stationary instrument is exposed to sunlight it will read one or two degrees above the air temperature.

But the greatest factor in creating differences between neighborhood thermometers on a

clear, cold winter morning is relative altitude. On still, winter nights the cold air slides down hill, and a few hundred feet of altitude on a hillside may mean 10 degrees difference in air temperature. A depression in the ground will contain a puddle of air much colder than anything around it.

Winter Temperature Differences in Cities. Clear, cold, winter nights in the cities, especially when the ground is snow-covered, lead to local differences in temperature between points located close together, amounting often to 5 degrees Fahrenheit and sometimes even to 25 degrees. The air in contact with the snow becomes chilled to a greater degree than that above it. On slopes this colder air slides down into the lowlands and hollows On flat areas the layer merely thickens during the night, and the intensity of cold is not so great as at the foot of a slope. Naturally second stories of houses are warmer than first stories, and loftier apartments are relatively warmer still. But what the higher parts of buildings gain in warmth on still nights they lose in windy weather, for they experience not only a slightly lower temperature but also much stronger winds.

Thus on quiet, cold nights, the thermometers at the Weather Bureau stations of the large cities, which are of necessity located on tops of tall build-

ings, give higher readings than instruments at street level below, and on windy nights a lower reading. On windy nights velocities are much higher at the stations. For instance, in New York City the velocities on the tops of the down-town skyscrapers have been found to be twice as great as those in Central Park.

Medicine Hat, "Cold Wave Factory." Medicine Hat, a little city in southeast Alberta, 2,144 feet above sea level and 300 miles east of the Rocky Mountains, has long been known as the "Cold Wave Factory." It chances to have a name that appeals to popular fancy, and also is most favorably situated for pronounced weather changes Its range of temperature is astonishing, from 51° below zero F. to 108° above. Its chinooks are famous, the temperature in winter having risen 70 or 80 degrees in a few hours, causing the snow to disappear miraculously. But the town is not a "cold wave factory."

The common Alberta type of storm first comes under observation in that province, but it may at times originate much farther north. It enters civilization where Medicine Hat is one of the first weather stations to feel it. The widespreading Norther, which often penetrates with its icy chill into the Gulf states, usually comes down through Alberta, and so also many of the cold waves affect-

ing the eastern United States break first over the stations in the Canadian Northwest. Even though the cold air that flows over Medicine Hat can affect but a small strip of country, the occurrence of a cold wave in that region is a warning to eastern North Americans that other, uncharted cold air masses may soon appear farther east.

The Cold Wave. When in winter the weather is moderately warm, with a southerly wind blowing and a low and falling barometer, look out for colder weather soon, perhaps a cold wave. At times a cold wave may come without warning, when a cold wind drops suddenly from uncharted Labrador. Usually, however, the approach is more gradual, allowing the Weather Bureau an opportunity to give warning 24 hours or more ahead.

The cause of the cold wave is a considerable transportation of cold air. It is usually marked by an area of high pressure on the cold, northern plains, with low pressure to the southeast. Nature, in seeking equilibrium, is sending the icy current into the area of low pressure southward. The zone where the cold wave strikes the warm south wind is usually marked by rapid condensation of some of the latter's moisture, and as it passes there is a brief period of rain or snow, sometimes with thunder and lightning, and pres-

ently the mercury drops rapidly and persistently to frigid limits. The great cold wave of January 3-6, 1924, advanced now rapidly, now slowly, into the southeast. It was marked not so much by extraordinary cold on its first appearance in the north and a rapid sweep southward, as by the enormous volume of cold air and by a moderate degree of warming as it progressed, owing to an earlier chilling of the ground. Thus this cold wave was of extraordinary severity in the southeastern states, though it did not come very suddenly.

A Cold Morning Thought. On a morning when the mercury has dropped low and everyone is shivering, take comfort in the thought that the air about you is warm enough when compared with some places where people live the year round. The coldest inhabited spot on earth, so far as recorded, is Verkhoyansk, in northeastern Siberia, where the thermometer has registered 90.4 below zero Fahrenheit. The natives in this region live in double, practically airtight tents. It is so cold that snow is too limited for making igloos.

But —90.4° F. is the lowest record only at the ground. High aloft much colder readings have been made by means of sounding balloons which carry recording instruments far up into the atmosphere. The very coldest place of all was 10

miles up in the air above the Island of Java whence a record of 133 degrees below zero F. was brought down. This suggests what the airplane pilot must endure during ascents for altitude, though it is not so cold at great heights in middle latitudes as it is in the tropics. Temperatures of —60°, even —70° F. are within reach of the highest fliers in winter.

Snow and Temperature. Suppose that on a clear cold morning when the ground is covered with snow you should be ambitious enough to take a thermometer out for exercise before breakfast. To observe the air temperature keep the thermometer swinging or moving briskly. On a flat area of some extent where there is no breeze you will find that the air temperature at 3 feet above the snow surface is somewhat lower than that obtained when the thermometer is swung above your head. And if you lean over and wave the thermometer back and forth just above the snow surface you are likely to find a temperature several degrees lower than those previously observed. Then lay the thermometer directly on the snow surface. If the sun is not yet shining on it, the instrument will show a still lower temperature. Finally, stick it down a few inches into the snow and watch the mercury rise, probably to

several degrees above the highest air temperature observed.

An observation of this sort late one evening showed that while the air at 6 feet above the snow surface was —2° F. and at 6 inches above the surface was —8°, the temperature of the snow surface was —14°, while the temperature of the snow only 6.5 inches below the surface was 18.5° above zero Fahrenheit. The 6.5 inches of snow between the surface and the interior of the snow covering thus caused a difference of 32.5 degrees. Snow, with its included air, is an efficient insulator and keeps the heat in, while the snow surface, on losing much of its small store of heat by radiation and evaporation, becomes extremely cold on clear nights. This coldness of the snow surface is largely responsible for the very low temperatures of clear nights when snow is on the ground. Even on sunny days the snow results in lower air temperatures than if the ground were bare, for the snow surface temperature can never rise above 32° F. and, therefore, the snow cannot warm the air to higher temperatures. The bright sunlight, however, both direct and reflected, may raise the air temperature to 40°. Day as well as night, therefore, snow favors low air temperatures.

Hilltops Warmest in Cold Snaps. On clear,

windless mornings in cold weather the hilltops are warmer than the hollows. Cold air slides down hill and forms puddles and lakes in which the thermometer registers much lower than on the slopes above. A 20-minute excursion with a sling thermometer at sunrise on February 18, 1922, at Worcester, Mass., proved this point most effectively, for it showed that there were actual differences in temperature amounting to 10 degrees Fahrenheit between the top of a hill 250 feet high and its base, and disparities of 5.5 to 7 and 8 degrees in a distance of 100 yards, with only 10 to 30 feet difference in elevation.

In hollows the temperature ranged from —10° to —16° F., and on moderate slopes from —8° to —6° F.

In windy, cold weather, the hilltop is colder than the valley, which profits by protection from the wind. Again, where the difference in altitude is a material one, the usual decrease of temperature with elevation makes the hilltop the cooler.

Winter Temperatures Aloft. In summer the lower part of the atmosphere is much warmed by the warm earth; in winter this effect is less marked. Thus we find at a latitude of about 40 degrees, in the United States the average air temperature in summer is 77° F. at the surface and only about 45° at an elevation of 2 miles. In win-

ter, on the other hand, at the same latitude the average surface air temperature is 28° and the temperature at 2 miles, 16° F. Hence, where the fall in temperature in ascending 2 miles is 32 degrees in summer, it is only 12 degrees in winter. Between 2 and 5 miles up there is little difference between summer and winter rates of temperature decrease with altitude, and, at any level, winter temperatures are about 25 degrees below summer temperatures. As we go still higher, however, we find a smaller seasonal change till at 7 miles the temperature remains about —65° F. throughout the year. An aviator, then, who attempts to make an altitude record must be prepared for bitter cold at any season. In February Schroeder observed a temperature of —67° F. and Macready —60° C. (—76° F.) at an altitude of about 33,000 feet over Dayton, Ohio. The normal temperature at this elevation is about as low as the lowest surface air temperature ever observed in the United States, which is —68° F.

Sun Dogs and the Heavenly Cross. Several spectacular optical phenomena sometimes accompany the solar or lunar halo or occur without them, among them the sun dogs, pillar of light, and the "heavenly cross." The initial cause seems to be much the same for all of these, the presence of ice crystals in the air, usually composing the

cirro-stratus clouds that herald the approaching storm.

Sun or moon dogs are bright spots seen at either side of sun or moon, more often in winter than in summer, on a circle of 22° radius of which sun or moon is the center. They often have the colors of the corona, with red predominating.

Occasionally a vertical column of sheen extends above and below the sun, or perhaps more often, the moon, and this is known as a light pillar. More rarely may also be seen a horizontal bar of sheen, to form with the pillar the "heavenly cross." It may be of any color, from white to red, its color being always that of the sun, and is sometimes seen at sunrise or sunset. The phenomenon can be duplicated by looking at the moon or sun through a polished copper screen-netting from a distance of 20 feet. In the sky the cause is evidently the reflection of the rays of moon or sun on the vertical sides and horizontal faces of columnar crystals.

Ice Flowers. Frost flowers of beautiful, indescribably delicate design are sometimes formed on the exposed ice of northern lakes and streams in periods of intense cold. They appear in highest degree of perfection on surfaces that are close to open water, where they may rear their fern-like forms even as high as several inches. Or

they may lie about like feathers, as if the plumage of some white bird has been strewn over the ice and frozen flat upon it.

They result from the building up of ice crystals of types which are also found in snowflakes. The reason for some of the strange forms, notably the feathers, is believed to be the presence of chemical impurities in the air, especially ammonia. The most favorable conditions for their formation is when intense cold follows a warm spell during which vapor coming from open water has drifted over near-by ice, where much of it is deposited on nuclei as wonderful flowers and feathers.

John Burroughs, writing of the Hudson River, said: "A beautiful phenomenon may at times be witnessed on the river in the morning after a night of extreme cold. The new black ice (formed where ice-harvesting has been in progress) is found to be covered with a sudden growth of frost-ferns—exquisite fern-like formations from a half-inch to an inch in length, standing singly and in clusters, and under the morning sun presenting a novel appearance. They impede the skate and are presently broken down and blown about by the wind."

Ground Does Not Freeze at 32° F. Though we commonly think the ground freezes as soon as the temperature reaches 32° F., the freezing point

of pure water under ordinary conditions, observations of the temperature at which the soil actually freezes show temperatures from 2 to 9 degrees below 32°. This reduced freezing point is essentially the result of salts in solution in ground water. The low freezing point of the soil is a factor which prevents the ground from freezing to greater depths than those we are used to.

In the coldest regions, however, mostly where the mean annual temperature is 28° or lower, the ground freezes to depths limited only by the interior heat of the earth. In mine tunnels in Spitzbergen, under surfaces swept bare of snow, frozen ground has been found to a depth of 1,000 feet, and out to some distance under the ocean bottom. Such depths never thaw. Enormous areas in northern North America and northern Eurasia have such frozen soil.

Ice Pillars and Ground Heaving. During an open winter, or in the fall and spring, one will often notice pillars rising up out of the bare ground of gardens, paths or roadways. These small columns of ice commonly stand together in groups, frequently several inches high and capped with particles of soil or little stones. Even larger stones may be loosened or slightly raised from the surface by the freezing of the ground beneath. The heaving of the surface soil

by this process is responsible for much of the winter killing of wheat.

When the water in the soil starts to freeze, it must expand. If the whole surface is freezing, it cannot well expand sideways, and downward expansion is obviously less easy than upward. Hence these pillars of frost are forced up out of the ground sometimes carrying bits of the surface with them. In the same way, in very cold weather, milk in milk bottles freezes and expands, and you find the cap removed from the neck of the bottle and perched on the top of a column of frozen cream. Just as the cream column rises as a cylinder from the circular neck of the bottle, so the frost column retains the shape of the small aperture through which it emerges.

This growth of ice up out of the ground tends to bring moisture from lower layers to the top where it can evaporate more readily. The soil below is somewhat dried by the process, but the surface, after a slight thaw, is likely to be particularly slippery and muddy.

Cold Rain Leaves Sidewalks Dry. Surface temperatures of the ground or trees cause interesting phenomena in connection with snow or rain, apart from the usual features of the snow or ice-storm. Just as warm rain falling on a sidewalk may leave its surface dry, so, too, chilled rain

may fall on brick or asphalt without wetting it. In the one case the hot surface evaporates the raindrops as fast as they strike it. In the other, rain, cooled below its freezing point striking a surface equally cold, is instantly partially converted into ice.

Some snowstorms, especially those of the late fall and early winter, leave trees and shrubbery and tall grasses white with crystals, while the ground shows no trace of snow. The reason is that in the radiation of heat the ground has so much to give up that its temperature remains above freezing, while limbs, twigs, and grass blades, dead leaves, and the needles of the evergreens have been reduced to below freezing. The snow falling upon them remains unmelted, while that which reaches the bare ground is quickly converted into water.

Weather Healthful Last Quarter 1923. During the last quarter of 1923 the populous portions of the United States and Canada experienced unusually favorable weather from the general health standpoint. There was a considerable deficiency of cold windy weather, snowy days and rainy days. In consequence, there were long periods of quiet sunny weather with the diurnal changes set on a moderate plane of temperature. We usually had the temperatures appropriate for our own lati-

tudes for those months and were not struggling most of the time with cold air imported from more northern latitudes, as is so often the case in late fall and early winter. To the windswept and occasionally snowbound people of the Great Plains, Rocky Mountain and Plateau regions, however, these three months were trying, especially after the last of November, when winter became well established.

Elsewhere winter did not suggest beginning till the second week in December, when the first killing frosts occurred in all but the coastal districts of the southern half of California, and when the first biting winds swept over the eastern United States to Canada, 30 to 40 or more degrees Fahrenheit colder than the southerly winds immediately preceding them. The trying weather of winter had arrived at the end of December.

SECTION XXIV

WINTER IN THE HOME

Storm Windows. When winter weather is only a few weeks away, and the price of coal a matter of serious moment to most people, means of keeping down the fuel bill receive perhaps more attention than ever before. The trend of late years has been away from storm windows and toward weather strips. Yet the good old-fashioned storm window does what no weather strip can do.

When the wind is blowing directly upon the single thickness of window-pane the glass may take on a temperature far below freezing, in which case frost and ice will form in abundance. The presence of such cool areas covering a relatively large wall space of a room necessarily acts as effectively as a cooler as would frosty piping through which cold brine was being circulated. The combination of icy wind and the glass constitutes an effective refrigerating machine.

The presence of a storm window creates an air space between it and the inner pane, and the cooling effect of the outdoor air is decreased to a remarkable degree. No longer can the wind blow

through the cracks at high speed; the effect of a weather strip is also obtained. Instead, a calm exists next the inner pane, which takes a temperature approaching that of the room. The storm sashes are of particular value on windows against which the coldest winds blow. Of similar, though, of course, much less value, is the practice of pulling down the shades at night, which, it is estimated, results in a 20 per cent reduction of heat loss through the windows.

Window Frost. Window frost forms when a window pane is cold enough to chill indoor air below its dewpoint, and when that in turn is below the freezing point. Low temperatures and high winds outside will be most favorable for maintaining a cold pane. A storm sash, on the other hand, will protect the window and reduce the amount of frost decoration inside. The more moist the indoor air and the higher its dewpoint, the more readily will frost form, but if a room is very warm the window pane is likely to be not cool enough and the air too dry for a frost display. Jack Frost, then, like other fairies, finds night the most suitable time for his work; then outdoor temperatures are lowest, there is no sunlight to melt the tracery, and the rooms are coolest. The frostwork will generally occur first on the lower part of a sash and on the edges. Air coming in

contact with the top of the pane cools and settles, becoming successively cooler as it slides down the pane, until finally it is cold enough for condensation to take place. The cold air also collects around the margins of the pane where the frame prevents free circulation.

Forms of Frost Crystals. When frost starts to form on a window pane the first crystals will commonly appear around some little irregularity in the surface, a scratch, a projection, or a little dirt. Soon the pane is covered with fine crystals, giving a granular appearance. The tendency is, however, for existing crystals to grow instead of new ones forming, and even for large crystals to grow at the expense of smaller ones, which slowly evaporate, allowing their moisture to condense again on the big crystals. Clear areas, then, tend to appear around these growing crystals. Mr. W. A. Bentley, of Jericho, Vermont, has made many beautiful microphotographs of window frost. The crystals show six-pointed stars often elaborately subdivided, graceful fronds, fine filaments, delicate, little, curled feathers of frost, and the familiar branching forms suggestive of ferns or Christmas trees. The beauty of frost forms such as these may be appreciated by those who might fail to notice the small exquisiteness of the snowflake.

Why Winter Indoor Air is Dry. When in winter the air indoors feels abnormally dry, it is not because of steam heat or furnace heat or any other particular kind of popularly called "dry heat." It is simply a matter of temperature. The house is warm, and in fair winter weather the air is very dry, even out-of-doors. When the cold air enters a house where the temperature is at least 65° F., and in the American home it is usually higher, the dryness is highly intensified. Warm air can include as part of itself much more water vapor than can cold air, and therefore what little moisture is carried into the house becomes but a small percentage of what might be present after it assumes the temperature of the room.

Despite the fact, however, that the air of the room is much drier relative to the possible humidity than the cold air outside, in reality it contains a greater amount of water, as tests have proved, the difference commonly amounting to 5 per cent. The reason is the presence of moisture exhaled from the lungs and derived from cooking, from plants and water surfaces, and from steam heat leakages. Still, desert dryness prevails.

Moist Air Indoors Saves Coal. To increase the moisture content of the air in the house in winter is to secure a comfortable warmth at a lower temperature than when the air is permitted to remain

at its normal cold weather ultra-dryness. In any heated house a considerable amount of water vapor may be added to the atmosphere without producing dampness, and, of course, a proper degree of humidity is healthful to human beings as well as to furniture. Body evaporation is less, and the air does not so thirstily rob lungs, throat, and nose of the moisture that their well-being demands. For this reason, a temperature which would seem chilly in dry air is high enough when humidity is sufficient. Thus, the coal bill diminishes as the moisture increases.

More and more people are realizing the undesirability of excessively dry indoor air and are placing open water receptacles in their rooms. Specially designed tanks, with or without wicking, are made for attachment to radiators, and for steam-heated houses special noiseless steam-emitting valves have been invented. At best, however, such devices only mitigate the excessive dryness, for unless a house is unusually tight large masses of new, dry air are entering faster than new vapor can humidify them effectively. Nevertheless, a partial help is better than none in making our houses more comfortable on less fuel.

Cellars Are Dry Again. With the lighting of the furnace fires the cellars lose their warm-weather dampness. The walls and pipes are no

longer dank and cool. The chill which prevailed even in hottest weather goes. People say their cellars have dried out. Yet, doubtless, there is just as much moisture there but it does not so nearly "saturate" the warmer air. Let the fire go out and the chill, subterranean dampness would soon reassert itself.

The reason for the change is that with rising temperature air can contain much more water as invisible vapor. At 60° F. it can have over twice as much moisture as at 40°, and at 80° more than twice as much as at 60°. In the average cellar considerably more moisture than was present before the fires were lighted could be added, and the air would still seem dry.

Summer Heat Warms Winter Cellars. Down in the ground at a depth of from 30 to 50 feet it is a little warmer in midwinter than in midsummer. In fact, the highest temperature, in the small annual range there, comes at the same time that the lowest temperature occurs at the surface. The ground is a very poor conductor of heat, and for that reason the daily variation of surface temperature does not penetrate to a greater depth than two or three feet, and requires hours to reach even that shallow depth with its feeble effect on the temperature. Similarly, the heat of summer gradually extends its influence downward, though

ever to a weaker and weaker degree, just as heat applied to one end of an iron bar eventually works its way to the other end. In the case of iron, however, the transfer is far more rapid and more effective than in the ground. So poor is the transfer of heat there that seasonal changes rarely extend beyond a depth of 50 feet, and to accomplish this requires six months, or from midsummer, when the temperature wave starts down, till midwinter, when its weak remnant arrives.

The effect is felt in subterranean chambers, even in the ordinary house cellar, where the walls are cool in summer and relatively warm in winter, no great amount of heat escaping through them into the ground. Where winters are cold many householders take advantage of the poor conductivity of loose soil and other material by making embankments against the outside walls of their cellars.

Clothes Dry Below Zero. No matter how low the temperature of the atmosphere, snow and ice evaporate almost constantly. Experience of Arctic explorers proves the fact under greatest extremes of cold. One of them tells us that thin plates of ice, made in a shallow dish, and suspended in the open air in exceedingly cold weather, disappeared in a few days, and that washed clothing hung out-of-doors under similar conditions,

frozen stiff, dried perfectly in a week. Icicles that we commonly see forming from sun-melted snow or window-ice by day, invariably tend to become thin and sharp-pointed when melting stops, or over-night, as the dry, though cold air circulates about them. Likewise, ice on shady sidewalks slowly disappears, and children's slides deteriorate rapidly in dry weather, even when not in use.

Weight of Snow on Roofs. How great is the weight of accumulated snow and ice which roofs must support in winter? In the northeastern United States and eastern Canada about the maximum to be expected is 50 lbs. per square foot on a flat roof, which is the weight of a layer of water nearly 10 inches deep. Near New York City, architects allow for 40 lbs. per square foot. A steeply sloping roof will provide a larger receiving surface for a given amount of snowfall, and so will have to support less per square foot than a horizontal roof. Another advantage of the steep roof is that it facilitates the sliding off of snow and ice, though in cities wire snow holders are commonly used to prevent this. In the Sierras and Cascades the weight of snow may reach 250 lbs. per square foot, a ton for every 8 square feet, or three times the maximum for eastern North America. It is not surprising, then, to find

houses built with very steep roofs in such places as Crater Lake, Oregon. Objects buried in deep snow are often wrecked by the pressure. For instance, the Weather Bureau observer at Summit, California, reported that the substantially built steel and sheet iron rain gage looked as if a tornado had struck it when he dug it out of the snow in March, 1915. Even the guy wires were broken.

Collapsing of roofs occurs in unusually snowy winters, especially where snowfall is usually light and where consequently a relatively less substantial type of construction is the rule. For example, at Seattle, Wash., Feb. 2, 1916, on the third day of a heavy snowstorm following previous snows, the dome of the St. James Catholic Cathedral collapsed under the weight of 2½ feet of snow. The tragedy attending the collapse of the Knickerbocker Theater in Washington, D. C., occurred just before the end of the 28-inch snowfall of Jan. 27-29, 1922, when the added weight on the roof had reached about 15 lbs. per square foot.

How Icicles Form. When roofs are heavily covered with snow and the temperature stays below freezing, long icicles may develop, hanging their daggers from the eaves or the window sashes, and imperiling the heads of passersby when a thaw arrives. The formation of such icicles is dependent upon the blanketing effect of the snow-

cover. Icicles form readily also on eaves of sheds, barns and uninhabited houses, and on fence rails, aqueducts, and cliffs.

In all such cases water from some source, often from snow melted by sunshine, runs down the roof, or other surface, usually protected by snow from the low temperature of the air. The water then comes out at the edge, where it is more or less rapidly frozen. The evaporation of the exposed water facilitates its freezing.

The house roof is warmed from the house below, and, thanks to the snow blanket, maintains a temperature above freezing. This suffices to melt a little of the snow in immediate contact with the roof. The water runs down to the eaves but freezes at the edge. As the process continues day and night, even in the coldest weather, the icicle becomes longer and longer. In a snowy winter, icicles 10 feet long and 6 to 8 inches in diameter are not infrequently seen. Smaller icicles form fringes on the lower margins of the upper sashes of windows. When the window frost melts, the moisture often runs down the crack between the two sashes and freezes, furnishing the moisture for these dainty little icicles.

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